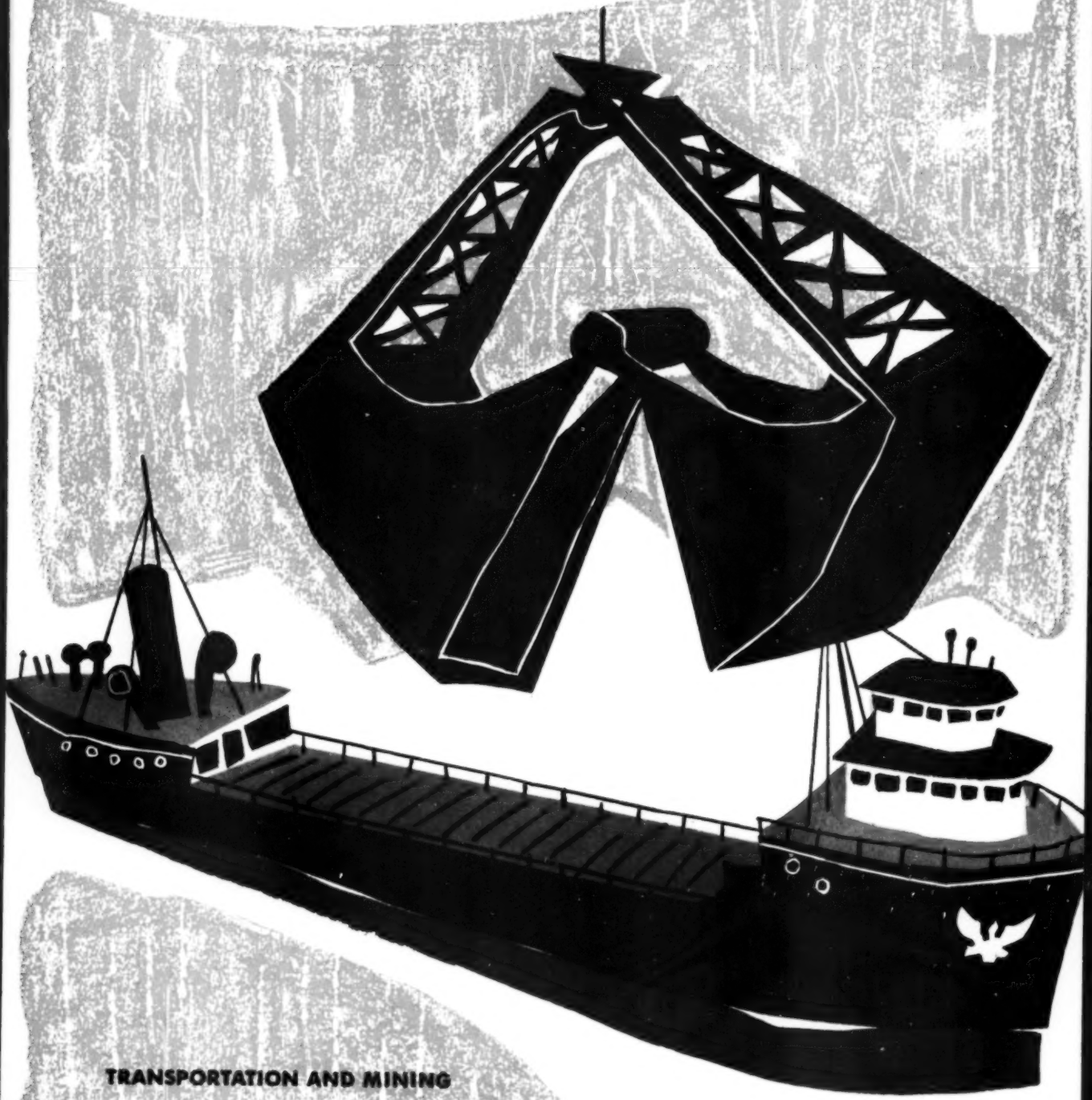
MINING engineering

JUNE 1954



TRANSPORTATION AND MINING

In Coal Preparation...

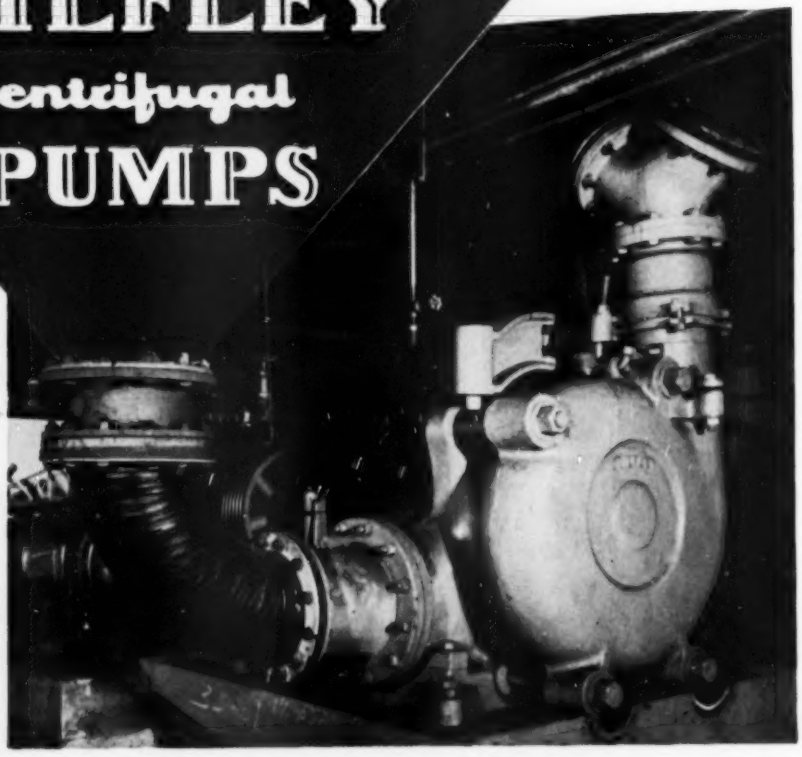
Wilfley Centrifugal Pumps { PRODUCE LOW COST PUMPING

MORE AND MORE ECONOMY MINDED PRODUCERS find that WILFLEY engineering lowers the cost of coal preparation by lowering the cost of pumping. WILFLEY Pumps operate continuously and efficiently without attention—deliver consistent cost-saving performance on every pumping job. Let us show you how WILFLEY Pumps can solve your pumping problems. Individual engineering on every application. Write or wire for complete details.

Continuous operation without attention • Minimum replacement of parts • Stepped-up production • Economical pump size for every requirement • Cost-saving efficiency • Designed for simple installation

WILFLEY centrifugal PUMPS

Write or wire for complete details.



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"COMPANIONS IN ECONOMICAL OPERATION"
Wilfley Acid Pumps

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MINING engineering

VOL. 6 NO. 6 JUNE 1954

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COVER

Increasing utilization of bulk foreign materials heightens importance of transportation as an economic factor in the mineral industry. The article on page 598 provides an interesting breakdown of the unit costs of transport by land and sea, with the latter inspiring Herb McClure's cover this month.

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— Personnel Service —

THE following employment items are made available to AIME members on a non-profit basis by the Engineering Societies Personnel Service Inc., operating in cooperation with the Four Founder Societies. Local offices of the Personnel Service are at 8 W. 40th St., **New York 18**; 100 Farnsworth Ave., **Detroit**; 57 Post St., **San Francisco**; 84 E. Randolph St., **Chicago 1**. Applicants should address all mail to the proper key numbers in care of the New York office and include 6c in stamps for forwarding and returning application. The applicant agrees, if placed in a position by means of the Service, to pay the placement fee listed by the Service. AIME members may secure a weekly bulletin of positions available for $3.50 a quarter, $12 a year.

MEN AVAILABLE

Mining Engineer, 29, desires employment with sound, progressive, active firm where excellence, efficiency, and safety are the production standards. Starting position not as important as an enterprising organization. Good scholastic record. Mining, engineering, and supervisory experience. Family, employed. M-83.

General Manager, 51, married, graduate mining engineer. Twenty-six years experience hard-rock mining, 5 years as superintendent and 11 years as general manager of mines. Available short notice. Domestic or foreign location. M-84-544-E-1-San Francisco.

Paleontologist, 41, married, B.S., M.A. degrees both in geology, Ph.D. near completion. Ten years experience nonmetals with some metal deposits. One year in Mexico on gypsum. Five years specializing diatomaceous earth and associated materials. Desires teaching position preferably in West or Midwest. Available immediately. M-85-474-E-6-San Francisco.

Mining Geologist, 49, good health, married, 3 children, fluent Spanish. Twenty-six years mining experience: 15 years managerial experience in conjunction with geological work, 11 years engineering, shift boss, mine foreman, and mine superintendent U. S. and foreign countries. Familiar with trackless and all phases of mechanized mining. Has proven record of low costs. M-86.

POSITIONS OPEN

Diamond Bit Salesman for complete line of diamond drill bits and reaming shells. Should have active accounts; some knowledge of diamond drilling preferred. Commissions. State territory and experience. Location, New York, N. Y. Y9960.

Mining Superintendent, preferably graduate engineer, with 5 to 10 years experience in open pit mining. Will be in direct charge of a crew of 100 men, and should have some appreciation of maintenance as far as machinery is concerned. Salary, $7000 to $8000 a year. Location, New York State. Y9937.

Electrical Supervisor, 28 to 35, with B.S. in mining engineering, and 5 to 8 years experience in heavy industry, preferably cement and lime. Capable of laying out and supervising installations and maintenance of electrical equipment. Experience with substation equipment and power contracts helpful. Salary, $4800 to $6000 a year. Location, West Virginia. Y9933.

Mill Supervisor, young, with some manganese experience, to supervise physical operations, for a strip operation with milling process starting with a log washer, through crushers, screens, and jigs to Wilfley tables. Salary, $6000 a year. Location, southwest Virginia. Y9917.

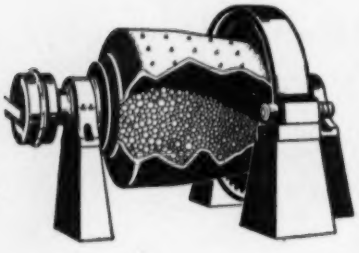
Milling Engineer with mining degree, for fluorspar mine and mill. Must be expert in fluorspar treatment by grinding, flotation, and Heavy-Media. Must have knowledge of latest milling science; be cost-conscious; and have industrial engineering (motion study) experience, etc. Salary, $7200 a year. Employer will negotiate fee. Location, Illinois. C1861.

Mining Engineers, B.S., under 35, to work as project engineer on various coal and ore beneficiation problems and study application of equipment to these problems. Involves use of Heavy-Media systems and/or alluvial jigs as well as crushers, screens, dryers, and all the company's materials handling components. Also includes problems in general field handling equipment. Salary open. Location, Chicago. C1884(a).

Engineers. (a) Mine Manager, experienced, for gold-copper mine in Argentina with flotation mill 9500 ft above sea level. (b) Mine Superintendent, experienced. (c) Mill Superintendent, experienced. (d) Mining Geologist, experienced. State types of deposits studied, knowledge of Spanish. Give salary requirements. F9900S.

Engineers. (a) Assistant Mine Superintendent, for large base metal operation in South Africa. Should be technical graduate with at least 5 years good mining experience. Three-year contract. Transportation for self and family, and salary while traveling. Climate and living conditions excellent. (b) Mine Captain for above company. Should have at least 4 to 5 years good mining experience. Three-year contract. Transportation for self and family and salary while traveling. Location, South Africa. F9844.

GRINDING MILLS



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WANTED
ASSISTANT MINE
MECHANICAL SUPERINTENDENT

Age 30-40, college graduate preferred. Should have some experience in repair of heavy underground mining equipment and surface operations. Salary open. Location Caribbean Area. In replying, please enclose recent photo along with resume.

Box F-8 AIME
29 W. 39 St., New York 18, N. Y.

MECHANICAL DESIGN ENGINEERS

Earthmoving experience with successful record in design and development of heavy mechanical equipment, crawler tractors, bulldozers or mining machinery preferred. Work includes layout and design of heavy machinery, leadership of design section. Send complete record and references. Location Salt Lake City.

Box E-6, AIME
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New York 18

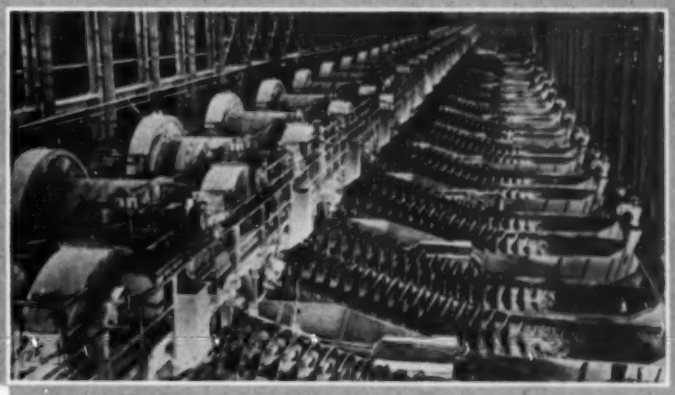
how MARCY MILL leadership in mechanical performance can help you cut costs

Grinding mills are selected on the basis of low-cost-per-ton output resulting from efficient, dependable mechanical and metallurgical performance. That's why so many successful mining companies throughout the world continue to order **and reorder** Marcy* Grate Discharge Ball Mills and Marcy Open End Rod Mills.

for example . . .

BEARINGS AND LUBRICATION

- the type of bearings and method of lubrication used are custom-engineered for each Marcy Mill to assure dependable, continuous operation, long life, maximum operating convenience on every installation...one of the many Marcy Mill features which result in low-cost-per-ton production.
- bearings are made with special Marcy Mill bronze, babbitt or micarta bushings.
- lubrication may be...
  - single or multi-bearing flood-oiling system with filtering, cooling and recirculation of oil.
  - by grease, oil or water.
  - automatic or by hand.
- hand operated oil jack for starting can be furnished if erection and operating conditions justify its use.
- water-cooled bearings can be furnished for dry grinding of hot materials.
- Marcy bearing design permits lifting the mill out of bearing base—always assuring proper alignment when reset.



Operating over 10 years without bearing replacement. These 10' x 10' Marcy Mills, with flood-oil lubrication, have been in operation more than 10 years without a bearing replacement.

*Both Marcy and Massco are registered trademarks.

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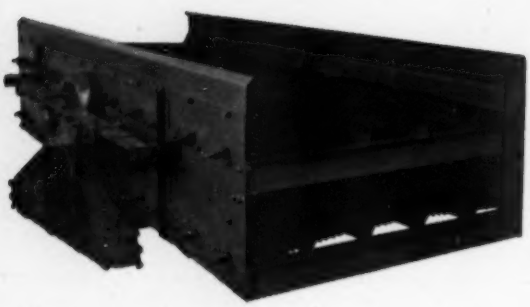
Denver 17, Colorado

OFFICES IN SALT LAKE CITY, EL PASO, 1775 BROADWAY, N. Y. C.

HEWITT HR ROBINS can cut your handling costs

with this complete

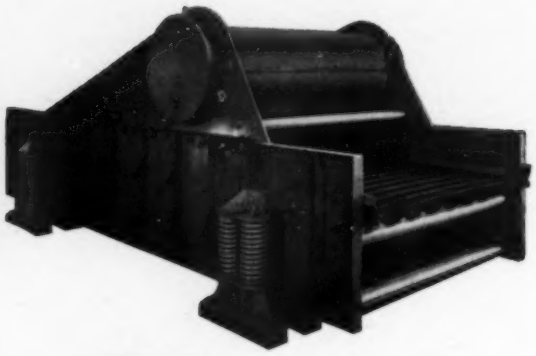
FOR SCREENING



GYREX°

Positive Stroke 4-Bearing Screens

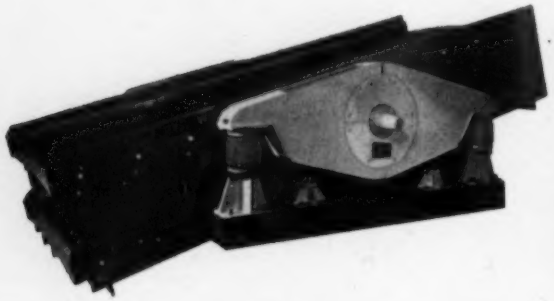
STROKES: ¼" at 1,000 r.p.m. and ½" at 625 r.p.m.
SIZES: Complete range of standard sizes from 48" x 78" to 72" x 192".
DECKS: Single—Double—Triple.
MOUNTINGS: Anvil-type cast iron base with *exclusive angle adjustment* for floor mounting—Steel I-beam base for suspended or rigid mounting.



ELIPTEX°

Horizontal Operating Flat Screens

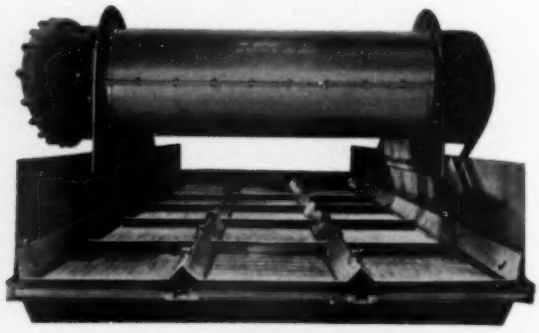
STROKES: 7/16" nominal at 1,000 r.p.m.—Other stroke and speed combinations available to meet special applications.
SIZES: All standard sizes from 36" x 96" to 72" x 240".
DECKS: Single—Double—Triple.
MOUNTINGS: Floor mounted or Suspended arrangement.



VIBREX°

Full-Floating, Unbalanced Pulley-Type 2-Bearing Screens

STROKES: Available in many stroke and speed combinations ranging from ¼" at 1,800 r.p.m. to ½" at 660 r.p.m. —All Vibrex screens have readily adjustable stroke to meet the most exacting operating conditions.
SIZES: All standard sizes from 16" x 30" to 72" x 192".
DECKS: Single—Double—Triple.
MOUNTINGS: *Exclusive angle adjustment* for floor mounting —Cable arrangement for suspended mounting.



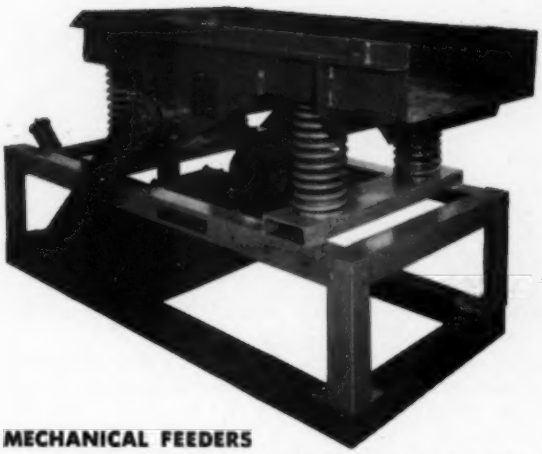
ELIPTEX DEWATERIZER

Specially Designed Eliptex Screen With Micron-Size Opening Stainless Steel Flat Rod Deck

STROKE: Extra-full stroke operating at high speed for maximum efficiency to handle even the most difficult dewatering problems.
SIZES: All standard sizes from 36" x 144" to 72" x 192".
DECKS: Single—Double.
MOUNTINGS: Same as Eliptex Screens.

line of Vibrating Equipment

FOR FEEDING & CONVEYING



MECHANICAL FEEDERS

A *fully mechanical* vibrating feeder that is easily maintained by your own personnel. Extremely high capacities at very low power consumption.

FEED CONTROL: Remote, wide range, variable speed controls available.

STROKE: Full 3/16" at 1,000 r.p.m. readily adjustable . . . ideal for handling material of varying characteristics.

SIZES: All standard sizes from 24" x 48" to 48" x 96".

MODELS: Standard—Heavy duty models and special pans and deck designs available . . . suspended or base mountings.

VIBRATING CONVEYORS

A continuously balanced vibrating conveyor offering longer units with higher capacities at lower horsepower than ever before available. Ideal for handling a wide range of materials be it wet or dry, lump or pulverized, packaged or loose, hot or cold, abrasive or corrosive.

SIZES: Standards from 8" to 48" wide up to 150' long with single drive.

STROKE: Full strokes from 1/4" to 3/8" at speeds of approximately 750 r.p.m.

MODELS: Standard—Heavy duty models and special pan designs and arrangements available.

FOR SHAKING OUT

CAR SHAKEOUTS

Will handle wet, compacted and even partially frozen loads. Capacities vary depending upon characteristics of material . . . Typical unloading time under 5 minutes per car.

MODELS: 5-Ton HD (Heavy-Duty) for handling up to 100 cars per day—3½-Ton GS (General Service) generally recommended for up to 10 cars per day. Both models available with companion twin-hook Car Shakeout Hoist.

STROKE: 5/32" at 1,500 vibrations per minute (easily adjusted for specific applications).

Patent No. 2,504,789

FOUNDRY SHAKEOUTS

Successfully used in steel, iron and non-ferrous foundries of all types (production and jobbing) handling castings weighing from a few ounces up to 60 tons.

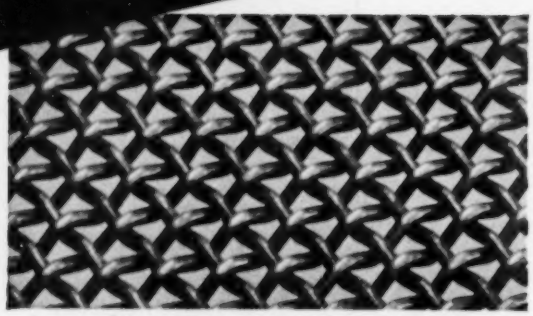
SIZES: From 2' x 2' to 8' x 10' in single units. Multiple unit arrangements up to 16' x 33'.

CAPACITIES: Up to 300,000 # (150 tons) in multiple units.

STYLES: Standard Stationary, Portable, Gravity Self-Discharging and Mechanical (Horizontal) Self-Discharging.

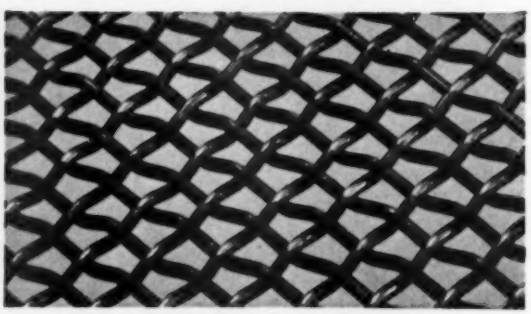
AND FOR YOUR SCREEN CLOTH NEEDS

HEWITT HR ROBINS can cut your handling costs with a complete



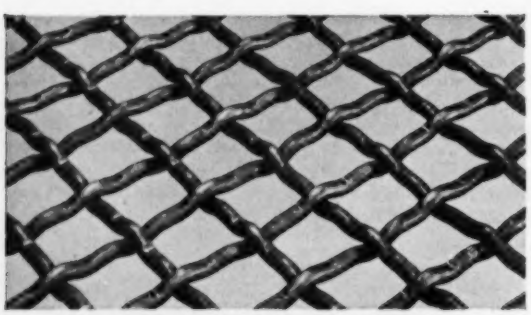
SQUARE OPENING DOUBLE CRIMP

All wires are specially crimped so that a spring tension permanently locks them together at each intersection. This guarantees tightness of weave and accurate sizing because openings cannot vary.



RECTANGULAR OPENING

Recommended for high speed sizing where accuracy is secondary. Rectangular weave provides greater open area hence higher capacity. Furnished with double crimp or flat top weave.

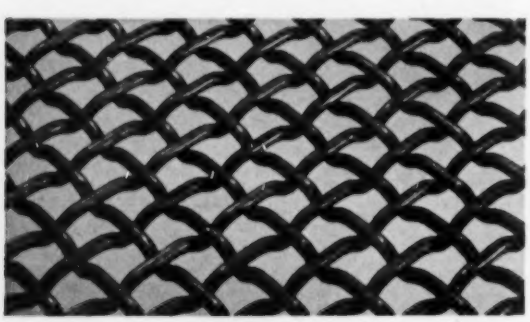


SQUARE OPENING LOCK CRIMP

Ideal for scalping. Has additional crimp to lock wires together under pressure to prevent wires from shifting as a result of impact and handling of oversize materials.

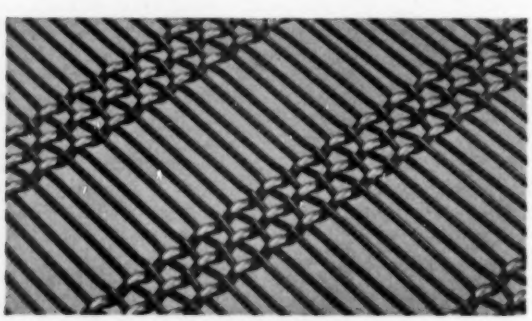
NON-SPREADER

Best for high speed sizing of coarse materials. Heavy-duty wires assist in maintaining accuracy of opening even under impact of wedge-shaped stone and over-sized materials.



FLAT TOP

Crimp characteristics provide smooth screening surface. Absence of high spots, as in other types of crimp, permits free flow and reduces abrasive action of material. Assures longer wear, faster screening and less degradation.



NON-BLIND

Recommended for processing moisture-laden materials that plug or blind openings. Slotted openings kept free from blinding due to secondary vibration set up in longer span wires. Clustered wires carry heavy tension and are crimped to maintain width of opening.

line of Screen Cloth

Each Type of Hewitt-Robins Screen Cloth is Specially Engineered To Accurately Size Large Tonnages... Last Longer... Cut Your Screening Costs

Hewitt-Robins Screen Cloth guarantees overall sizing accuracy through precision-weaving of individual screen cloth wires. You get longer service because Hewitt-Robins utilizes a full range of metals in its selection of wire to assure that each panel of screen cloth is matched to meet individual job requirements. Types of wire range from genuinely oil-tempered through spring steel, stainless steel, enamel-coated and on to special alloys of extraordinary corrosion and heat resistant properties.

In specific installations where the more abrasive materials such as coke, iron ore, stone, gravel and coal are handled, specify Hewitt-Robins Super-Gyraloy. It's the specially treated oil-tempered wire that combines hardness—stiffness—elasticity—ductility—toughness... and must pass exacting laboratory tests for uniformity of these properties.

For operations involving a dust factor aggravated by moisture (as in sizing fine coke and iron ore) specify Hewitt-Robins Super-Gyraloy Enamel Coated Screen Cloth. The enamel coating prevents the build-up of the blinding compound . . . protects the surface against moisture and averts oxidation of the metal.

Where initial cost is of primary consideration and abrasion is not excessive, Hewitt-Robins Gyraloy® spring steel screen cloth provides maximum efficiency and economy. For special applications Hewitt-Robins Screen Cloth comes in plain or galvanized steels, brass, phosphor-bronze, Monel and other ductile alloys.

Hewitt-Robins Screen Cloth is available in standard production size openings from 3/16" and coarser . . . wire sizes from .105" diameter up to and including 1" diameter.

For complete information regarding the kind, type and opening of Hewitt-Robins Screen Cloth to best fit your operation . . . give you highest screening efficiency at lowest cost per ton . . . contact Hewitt-Robins Incorporated, Robins Conveyors Division, 270 Passaic Avenue, Passaic, New Jersey, or your nearest Hewitt-Robins representative.

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Executive Offices, Stamford, Connecticut

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AMSCO DIPPERS FOR MINES

Mine superintendents with years of on-the-job experience, regularly specify manganese steel dippers on new equipment. Most specify by name—Amsco.

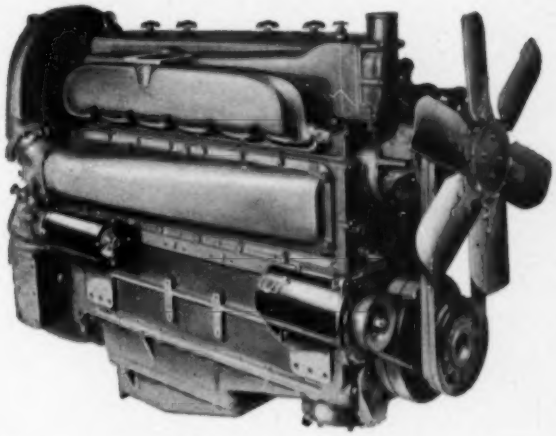
The reason is obvious. Amsco manganese steel dippers will stand up longer under rugged mine treatment and down time will be cut to a minimum.

Next time you order a power shovel or replacement dipper, specify long life right on your purchase order . . . *specify an Amsco manganese steel dipper.*

Brake Shoe

AMERICAN MANGANESE STEEL DIVISION
Chicago Heights, Ill.

NOW 300 HORSEPOWER



in GM "6-110" diesel engine

Improved Design Gives Still More Power Per Pound From Same Size Unit

Want more power—and production—from your heavy-duty equipment?

Stymied because you can't fit a higher-horsepower Diesel into your units?

Now you can get the power you need—and the increased production you want—with a new 300-horsepower General Motors "110" Diesel—the engine that delivers more torque in the working range. And, you can get them with no increase in engine size or weight.

Higher horsepower means faster operating speeds—high torque means more working power—for operators of all kinds of heavy-duty units.

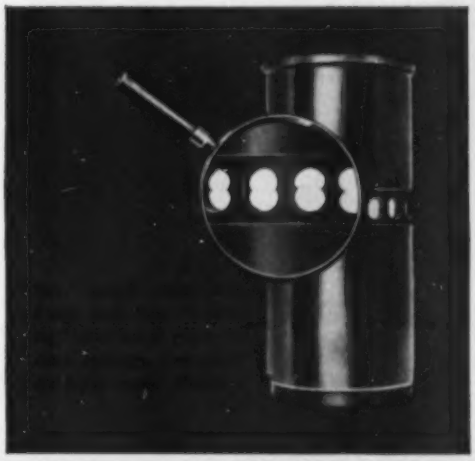
In off-highway trucks this combination means better hill-climbing, more trips per day, bigger pay loads.

In shovels it means faster digging and loading, more yardage, lower maintenance costs.

In drilling rigs it means more hole per day, faster round trips.

In tractors it means more power for pulling, pushing or "dozing."

Get full details on the new, more powerful GM Series 110 Diesels from your GM Diesel distributor. Have him show you that GM Diesels cost less to buy, less to run and less to maintain than any other Diesel.



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Books for Engineers

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Out of the Earth, The Mineral Industry in Canada, by G. B. Langford, *University of Toronto Press,* $3.65, 125 pp., 1954.—The author, who is professor of mining geology, and head of the Dept. of Geological Sciences, University of Toronto, has put into book form a series of talks by leaders of the Canadian mineral industry delivered under the auspices of the University Extension Dept. Excellent photographs, simple tables, and 40 line drawings and charts help to make important points of the story clear.

The Iron and Steel Industries of the South, by H. H. Chapman, *University of Alabama Press,* $7.50, 427 pp., 1953.—An economic study that follows these major divisions: historical and general background; natural resources; iron and steel industries; the southern market; potentials of the industry.

Resource Conservation, Economics and Policies, by S. V. Ciriacy-Wantrup, *University of California Press,* $6.50, 395 pp., 1952.—An analysis of goals of conservation to discover which ones are practicable and attainable by public and private agencies. In considering these goals, the author, who is professor of agricultural economics at the University of California, sets forth the basic problems of conservation. Our resources may be driven to depletion by our present tax, tenancy, and credit systems. An understanding of these forces will aid in their modification and thus encourage conservation.

Physical Geology, by L. Don Leet and Sheldon Judson, *Prentice-Hall Inc.,* $9.00, 466 pp., 1954.—Mr. Leet, chairman, Div. of Geological Sciences, Harvard University, and Mr. Judson, associate professor of Geology, University of Wisconsin, have written this book for readers who have had no previous training in science at college level. Accuracy, however, has not been sacrificed through oversimplification. The book is well illustrated and technical terms are defined in a glossary.

Concerning the Nature of Things, by Sir William Bragg, *Dover Publications Inc.,* $1.25 paperbound, $2.75 clothbound, 231 pp., 57 fig., 32 pl., 89 ills.—Popular reprint of the six lectures given at Royal Institute from 1923 to 1924. The author won the Nobel Prize in 1915 in physics for his work on crystal structures. The lectures on the structure of crystals reprinted here have become classics.

Directory of Geologists and Exploration Geophysicists in Member Societies of the American Geological Institute, *American Geological Institute,* 2101 Constitution Ave., N.W., Washington 25, D. C., Report No. 10, $2.50, 411 pp., April 1954.—This mimeographed directory was compiled from addressograph lists furnished the AGI in August 1953, and brought as up to date as possible when assembled.

The Mining Journal Annual Review, *The Mining Journal Ltd.,* London, $1.00, more than 250 pp., 1954.—A summary of events in the mining industry throughout the world during 1953. There are progress reports on the British Commonwealth's principal mining companies, and a country by country review of the mining industry, covering progress in practically every mining field of consequence in the world. Some 25 articles are devoted to the economic review of metals.

(Continued on page 570)

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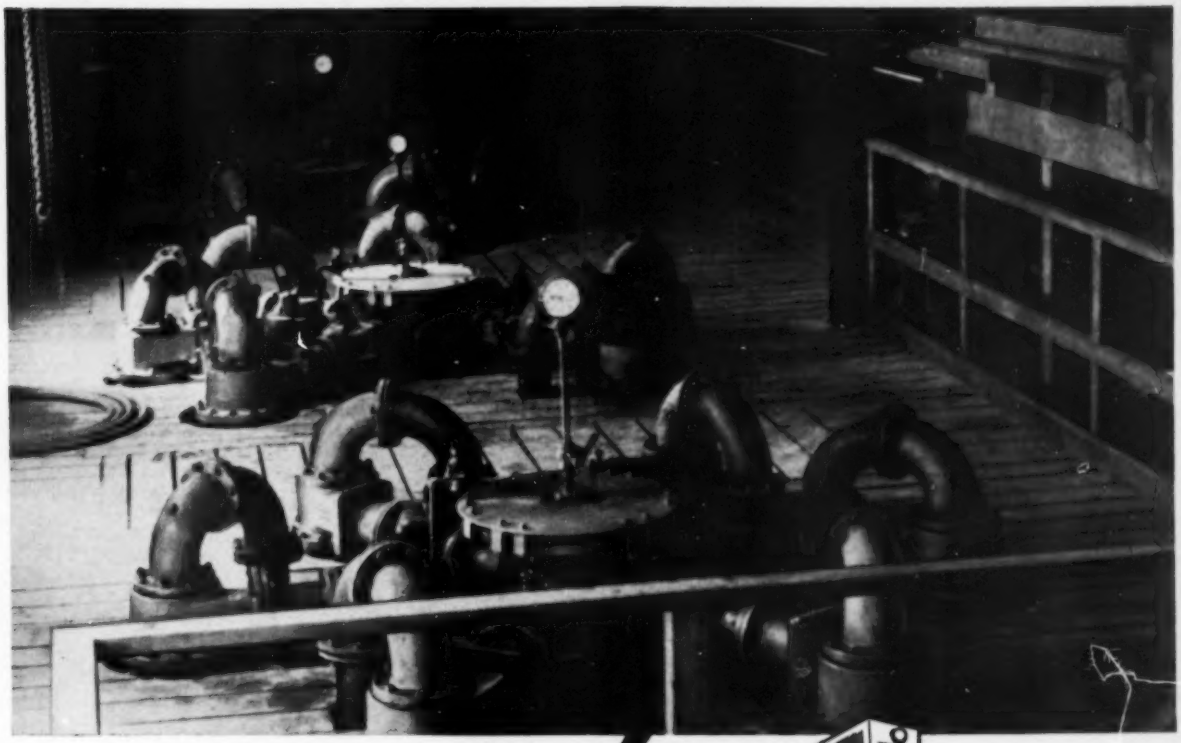

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2000 tons of useable mine backfill — enough to fill forty 50-ton gondola cars — are being produced every day by this DorrClone installation. In operation at a large Canadian gold mill, the installation consists of ten 12″ dia. primary DorrClones and six 12″ dia. secondary DorrClones with a spare for each stage. Feed to the primaries is 4500 TPD of mill tailings at 50% solids and final underflow from the secondaries is 2000 TPD of backfill with a percolation rate of 4″ per hour.

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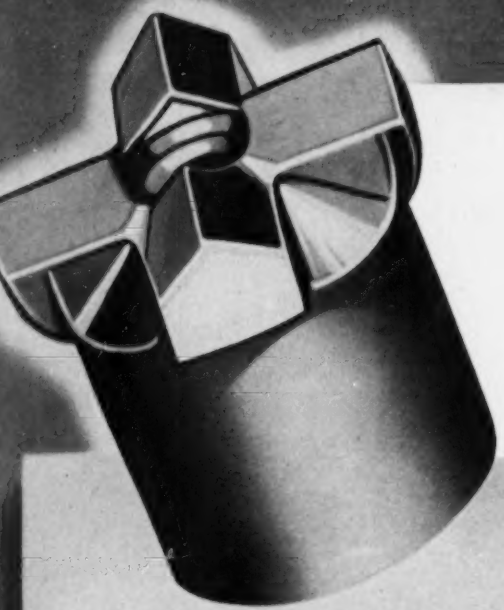

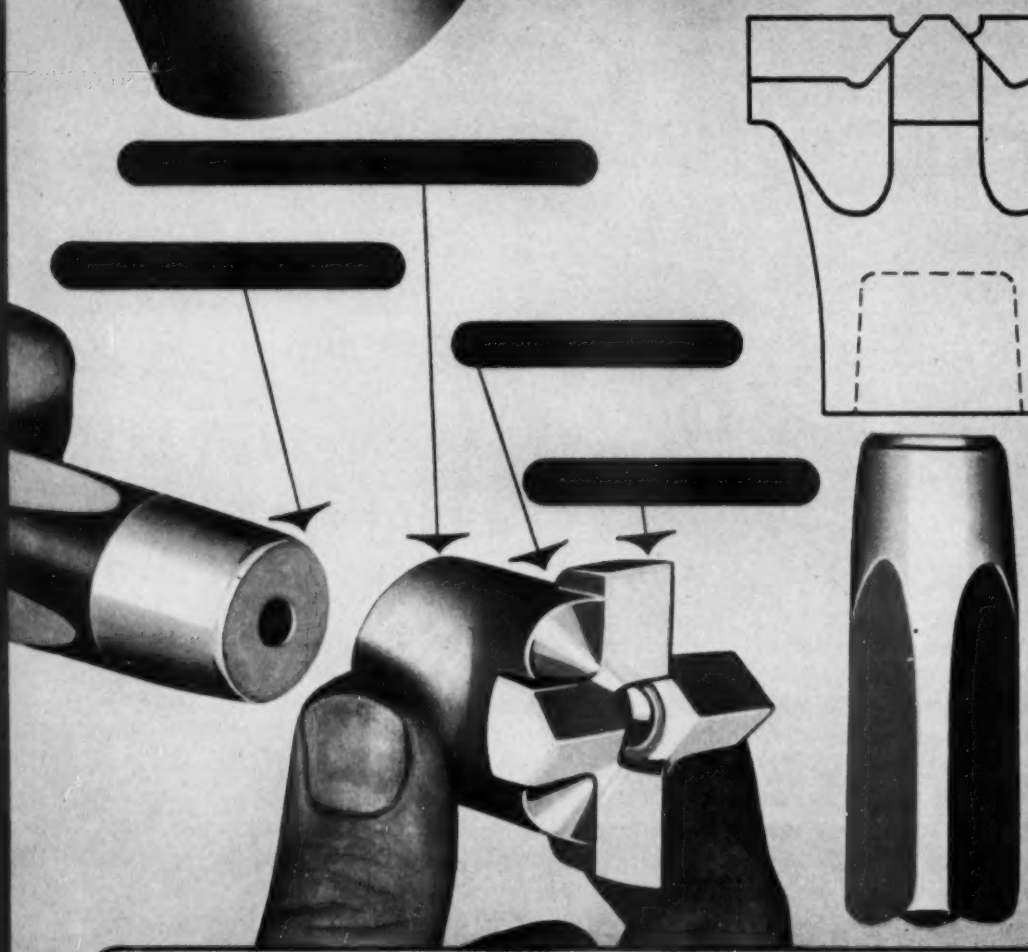

The union of the bit and the rod after drilling has a cohesive strength of several tons . . . A sharp blow of sufficient weight on the end of the bit skirt will serve to detach the bit from the rod.

SPECIFICATIONS

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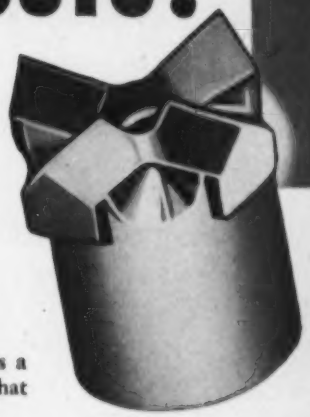
Cans are labeled showing size of steel socket, gauge of bit, and color.

way to cut drilling costs!

Use Le Roi-CLEVELAND one-use CRD Detachable Bits



Lower cost per foot of hole — that's the goal of everyone who has rock to drill. And that was the goal of Le Roi-CLEVELAND engineers, too. They didn't fool around with the problem either. Fifty years of experience in designing rock drills was put to work. The result — a one-use detachable bit that can save you money in a wide variety of applications.

This designing job wasn't done overnight. You can't produce the results our engineers were after in such a short time. Instead, these bits were put to work—and, for a number of years they have helped reduce drilling costs materially in mines, in quarries, and on construction jobs.

That's why we offer them to you now — with complete confidence in their ability to help you improve your rock-drilling cost picture.

These Features Mean Lower Drilling Costs for You

Faster Drilling Speed — Special offset gauge feature, which permits the use of thinner wings and a steeper reaming angle, greatly reduces binding and provides ample clearance for cuttings. Result is a free, fast-cutting chiseling action that gives you greater drilling speed.

Less Drill-Steel Breakage — The method of attachment used with the CRD bit eliminates threads on the drill rod. Since a drill rod is only as strong as the root diameters of its threads, the tapered threadless CRD design provides longer drill-steel life — reduces drill-steel handling and reconditioning costs.

Lower Rock Drill Repair Costs — Because the CRD bit design reduces binding in the hole, there is less strain on the rotation parts of your rock drills. Rifle bars, rifle nuts, and chucks last longer. You get more drilling done at lower cost.

Since no special equipment is needed to thread rods, you owe it to yourself to try a can of CRD bits. They're ideal for roof bolting and for use in your stopes as well as in your headings. A short trial will give you first hand information on the ability of these bits to cut drilling costs in your property as they have in so many others.

Bulletin RD-29 gives detailed information. A copy is yours for the asking — just write for it. RD-58

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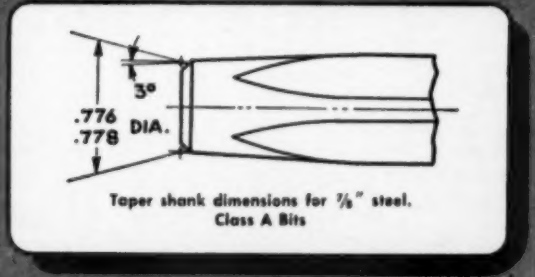
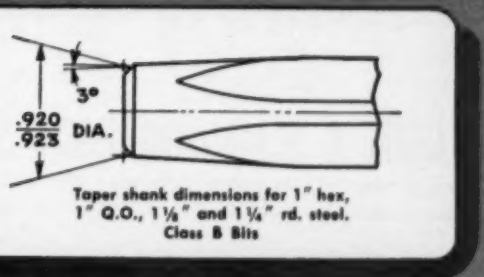


Taper shank dimensions for ⅞" steel.
Class A Bits



Taper shank dimensions for 1" hex, 1" O.D., 1⅛" and 1¼" rd. steel.
Class B Bits

The taper attachment shank used with the CRD bit is easy to make. You need no dies or other expensive threading equipment. Several simple, low-cost methods can be used for preparation — grinding, forging or machining.

Books for Engineers

(Continued from page 566)

Tugela Basin, A Regional Survey of the Catchment Area of the Tugela River and its Tributaries, *Town and Regional Planning Commission,* Natal, Union of South Africa, approx. $4.90, 143 pp., 25 color maps and illus.—Detailed information of interest to industrialists, economists, geographers, and general readers on a region of 11,000 sq miles, situated in the high rainfall area of the Union, between the port of Durban, the Witwatersrand, and the Orange Free State goldfields.

Scintillation Counters, by J. B. Birks, *McGraw-Hill Book Co. Inc.* $4.50, 148 pp., 1953.—This monograph consists of a historical introduction, enumeration of factors influencing the performance of the instrument, consideration of photomultiplier characteristics, discussion of pulse-height and time resolution, treatment of inorganic phosphors, photofluorescence, and organic crystalline phosphors, and a review of the author's photon exchange theory of fluorescence. The last two chapters cover the interpretation of properties of plastic and liquid phosphors, and major applications of the scintillation counter. Bibliography.

Structure and Properties of Solid Surfaces, edited by Robert Gomer and Cyril Stanley Smith, *University of Chicago Press,* $8.50, 491 pp., 1953.—Fourteen papers offer a critical review of present knowledge of the physics and chemistry of surfaces under the following broad headings: thermodynamics and theories of surface forces; the structure of a surface and means of determining it; growth processes of and on surfaces; processes on surfaces which leave them relatively unaltered. Among subjects covered are quantum mechanical theories of surface energy, and mechanical properties of crystalline metal surfaces.

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The Diamond Tool Industry in 1953, *Industrial Diamond Information Bureau,* 32-34 Holborn Viaduct, London, E. C. 1, England, free, 8 pp.—This ninth successive report reviews: scientific aspects, hardness and microhardness, truing of grinding wheels, impregnated diamond tools, rock drilling, diamond use and salvage, etc. References are given for each section. The bureau also publishes the **Bibliography of Industrial Diamond Applications,** a free monthly publication for firms, institutions, libraries, and individuals interested in the uses of diamond tools and their production.

Engineering Properties of Chicago Subsoils, by Ralph B. Peck and William C. Reed, Bulletin No. 423, *University of Illinois,* Urbana, Ill., $1.00, 62 pp., illus., 1954.

Geology of the Palen Mountains Gypsum Deposit, Riverside County, Calif., by Richard A. Hoppin, *California Dept. of Natural Resources,* Div. of Mines, Ferry Bldg., San Francisco 11, Special Report 36, 75¢, 25 pp., 1 pl.

Geology and Ground-Water Resources of Jackson County, Kansas, by Kenneth L. Walters, Bulletin 101, 91 pp., 9 fig., 10 plates, June 1953. Mailing charge 25¢. **Composition of Some Uranium-Bearing Phosphate Nodules from Kansas Shales,** by Russell T. Runnels, John A. Schleicher, and H. S. Van Nortwick, Bul. 102, part 3, 12 pp., 3 fig., October 1953. Mailing charge 10¢. **Experimental Separation of Iron-Bearing Minerals from Certain Kansas Clays,** by Frank W. Bowdish, Bul. 102, part 4, 12 pp. **Electron Microscopy of Fired Glaze Surfaces,** by Ada Swineford and Norman Plummer, Bul. 102, part 5, 8 pp., 4 pl. Both parts bound together, October 1953. Mailing charge 10¢. These bulletins are available from the *State Geological Survey of Kansas,* University of Kansas, Lawrence, Kan.

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XR54-8

Manufacturers News

New Products • FILL OUT THE POSTCARD FOR MORE INFORMATION • Equipment

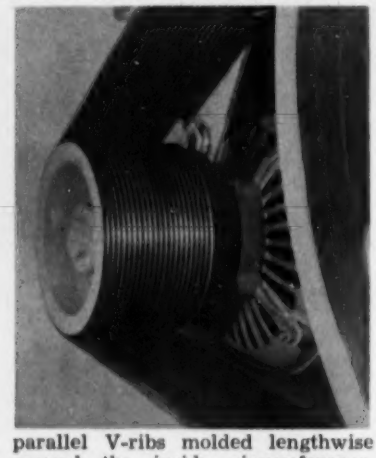
Short-Leg Stoper

Ingersoll-Rand has designed the RP-38 short-leg stoper with the right weight and power for rock bolting jobs. Claimed advantages of design

are reduced wear, reduced maintenance, and 20-lb saving in weight over machines of comparable power with resulting easier handling. Jackhammer or anvil block chucks are available to take ⅞ and 1-in. hex or quarter octagon steel. **Circle No. 1**

Poly-V Belt

Manhattan Rubber Div. of *Raybestos-Manhattan Inc.* recently introduced the Poly-V belt which has been under test in industry for 2 years. Now in production, the single, endless rubber belt has a series of



parallel V-ribs molded lengthwise around the inside circumference, and an uninterrupted member of

synthetic cords across the entire width. Belt contacts full surface of pulley (see diagram) and increased contact area is said to give 50 pct greater power transmission than multiple V-belts for same pulley width, or equal power capacity with one third less sheave width. Longer life is claimed. **Circle No. 2**

Longer Conveyors

Super Ustex-Nylon conveyor belt, which makes possible 3-mile center-to-center conveyor flights and vertical lifts in excess of 800 ft, is termed significant advance for mining and construction by *U. S. Rubber Co.* Belt utilizes cellulosic yarn, treated chemically to give three times strength of rayon fabric, and three and one half times strength of cotton duck. Only material comparable in strength is said to be steel cord. Cellulosic yarn longitudinal member is combined with nylon crosswise fabric for flexibility. Example cited for coal mining gives single flight 42-in. belt capable of carrying 1000 tph for 3 miles at 600 fpm. Savings through reduced number of flights are emphasized. **Circle No. 3**

Tire Tracks

Galanot Tire-Track is comparable to a crawler mount, but is designed to provide users of pneumatic tired construction equipment with maximum traction and flotation under ad-

verse conditions. Units manufactured by *Union Chain & Mfg. Co.* fit tire sizes from 6.00x15 to 18.00x26. Basic idea was proven on military vehicles in World War II and further developed since. **Circle No. 4**

Exhaust Cleaning

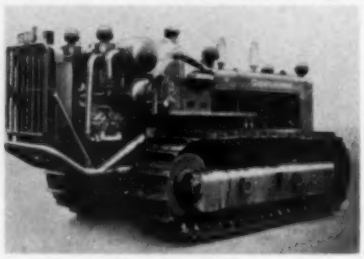
Oxy-Catalyst Inc. has released a job story on its Dieseler catalytic device to eliminate exhaust fumes from 4-cycle diesels. Overall size of the muffler is 7x12x27 in. Stated to have low back pressure, no moving parts, and no solutions, porcelain catalyst carrier does not require periodic maintenance. **Circle No. 5**

News & Notes

Formation of a wholly owned subsidiary, Allis-Chalmers, Great Britain Ltd., was announced by *Allis-Chalmers Mfg. Co.* Subsidiary will handle all A-C operations in British Isles and United Kingdom export markets . . . *Denver Equipment Co.* has enlarged quarters for its London office at a new address: 15/17 Christopher St., Finsbury Square, London, E. C. 2.

Big Portable

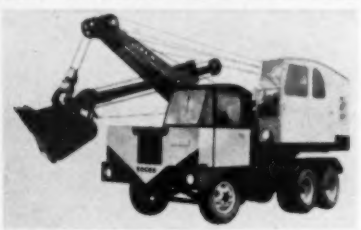
Remote and rugged areas can now take advantage of the *Le Roi* 600 CTM tractor mounted compressor. The 600-cfm compressor, equipped with side booms and twin wagon drill air feed assemblies can convert retired tractors that still have sound engines into fast moving integral



drilling units. Readily mounted on two leading makes of crawlers, International Harvester TD-24 and Caterpillar D8, the 600 CTM has independent clutch for direct connection to rear power take-off shaft. Standard equipment includes engine control, undercarriage and intercooler guards, air receiver, and oil bath air cleaners. **Circle No. 6**

Low Priced Crane

Thew Shovel Co. introduced the 6-ton Lorain MC-104 lowest priced Moto-Crane on the market, as its reentry to rubber tired crane field.



Fully convertible to ⅜-yd shovel, hoe, clamshell, or dragline, unit uses a 3-axle carrier termed rugged and completely new. **Circle No. 7**

Carbide Bits

A carbide-tipped prong type rock bolting bit has been developed by Carboloy Dept. of *General Electric* for drilling starter holes in ore or coal. New bits are designed for use in shale and formations softer than sandstone. **Circle No. 8**

Unit Fuel Injector

General Motors' Detroit Diesel Engine Div. announced changes for longer life and increased operating efficiency of GM unit fuel injectors for series 71 diesels. New engines have the improved injectors, and older models can be brought up to date with parts kits now available. **Circle No. 9**

Free Literature

(21) STEEL DATA: Available from *International Nickel Co.* is "Effect of Temperatures on the Mechanical Properties, Characteristics, and Processing of Austenitic Stainless Steels," by V. N. Krivobok and A. M. Talbot. This paper was presented in 1950 before the ASTM.

(22) CONSTRUCTION & PLANT MAINTENANCE: *Gardner-Denver Co.'s* bulletin PB 1 gives features and specifications of heavy duty, medium-weight and lightweight paving breakers. It also describes the sheeting driver, pin driver, spike driver attachments, and other tools. Specifications for G-D clay spaders, trench diggers, and single pad and triplex backfill tampers are given in bulletin ST-100.

(23) HARD-SURFACING: *Victor Equipment Co.'s* 45-page manual has information as to type of alloy to use, preparation, welding, and finishing procedures for hard-surfacing equipment parts. Emphasis is on diagrams of specific mining and beneficiation application situations.

(24) FLOTATION AID: Jaguar is *Stein, Hall & Co.'s* trade name for a natural vegetable colloid, hydrophilic guar gum. A booklet provides technical data on the product, stressing that it is cold-water swelling, produces high viscosity at low concentrations, develops its properties over a wide pH range, and that it is economical to use.

(25) GIVE 'EM AIR: Convert fuel into power not smoke. "Air for Your Engine" from *Cummins Engine Co. Inc.* is directed especially to owners of Cummins diesels, but it applies to better maintenance of any make or type of internal combustion engine.

(26) GAS REGULATORS: *Air Reduction Sales Co.* has a 36-page cross-indexed catalogue on cylinder, manifold, and pipeline regulators. Flow and pressure charts indicate at what point the regulators can be used to perform a particular job.

(27) HOSE COUPLING: *Titeflex Inc.* has a bulletin on quick connect-disconnect hose couplings for water, oil, steam, gas, and chemical lines.

(28) SAMSON CHAIN: *Chain Belt Co.* claims that the Rex-Z-Metal chain, made of a special heat-treated alloyed ferrous metal, has greater

strength, abrasion and corrosion resistance, yet is reasonable in cost.

(29) REFRACTORY SUGGESTIONS: Outstanding feature in *Battelle Memorial Institute's* bulletin, "Research Suggestions for Refractory Users and Producers," is a mean thermal conductivity conversion chart.

(30) SIDE LOADER: It carries like a straddle truck, delivers like a road truck, and stacks like a fork truck. *Baker-Raulang Co.'s* Traveloader, described in bulletin 1360, is a side loading lift truck designed to handle long, bulky loads, such as pipes, lumber, or rod stock.

(31) COPPER CONDUCTORS: Due to lifting of restrictions, *Anaconda Wire & Cable Co.'s* Hy-Therm copper conductors, for overhead transmission and distribution, are no longer in limited supply. Announcement points out that increased resistance to annealing permits higher current capacity and longer useful life without loss in conductivity.

(32) FIRST AID KITS: *Mine Safety Appliance Co.'s* type D first aid kits have a newly designed case with a hammered metal finish with a baked enamel surface to resist dust and grease. Circular points out simplified, illustrated instructions, improved packaging, and emphasizes the rigid system of quality control used in kit production.

(33) BENEFICIATION: *American Cyanamid Co.'s* mineral dressing dept. has a revised brochure on the beneficiation of tungsten ores. Described are various methods of processing, particularly froth flotation processes used on western U. S. ores.

(34) DIAMOND DRILL BITS: *Anton Smit's* diamond drill bit catalog No. 502 contains detailed, up-to-date price tables, standards and specifications, and information on latest developments. Also explained are Asco's consultation, resetting, and replacement services.

(35) MULTIPLE V-BELTS: *Goodyear Tire & Rubber Co.'s* brochure on engineering and design of multiple V-belts contains recently approved hp ratings. With this booklet, Goodyear claims that anyone with an ordinary mathematical background can solve problems of selection, installation, and service on V-belt transmission of power.

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for more information on items described in Manufacturers News and for bulletins and catalogs listed in the Free Literature section.

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51	52	53	54	55	56	57	58	59	60
61	Students are requested to write direct to the manufacturer.								

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(36) DIESELS: Detroit Diesel Engine Div., *General Motors Corp.* publishes a quarterly called "Power Parade." Current issue shows diesels drilling for oil, making roads, dragging oysters, lifting logs, and hauling gypsum.

(37) ION EXCHANGE: Every other month *Rohm & Haas Co.*, makers of Amberlite resins, publishes "Amber-Hi-Lites," designed to highlight new

developments—major and minor—in the rapidly advancing field of ion exchange. Abstracts of ion exchange articles are included.

(38) BATTERY MAINTENANCE: "Seven Rules for Maintaining Your Exide Ironclad Battery," an 8-page pocket-size booklet from *The Electric Storage Battery Co.*, emphasizes rules with cartoons.

(39) MATERIALS HANDLING: Preventive maintenance can save money in the operation of materials handling equipment. Folder from *Mercury Mfg. Co.* is entitled "Fork Truck Efficiency Test Tells When Corrective Measures Are Needed."

(40) ROCK BOLTING: An informative booklet from *Ingersoll-Rand Co.* on rock bolting procedures and techniques describes a complete line of equipment made for this application. The theory of rock bolting is explained by simple, clear illustrations and advantages and disadvantages are outlined. Sections deal with bolts, bolt holes, bearing plates, torquing, drills, and impact wrenches.

(41) PERFORATED STEEL: *Joseph T. Ryerson & Son Inc.* has a 4-page bulletin illustrating perforated carbon and stainless steel sheets and plates, for safety and screening use.

(42) CENTRIFUGAL PUMPS: *Worthington Corp.* has a bulletin on type UNB two-stage centrifugal pumps designed for pressures to 400 psi and capacities to 1300 gpm. The UNB pump is readily adaptable to boiler feed, refinery, mine, and other services.

(43) VIBRATING CONVEYORS: *Hewitt-Robins* booklet on vibrating conveyors is illustrated with pictures of typical installations. Technical details, capacity tables, and design dimensions are given on both the Rockermount and Springmount conveyors.

(44) DENSITY MEASURING: *Sierra Industrial Instrument Co.* has information on a nuclear-electronic method of indicating density of slurries or solutions, or of any fluid flowing in a pipeline. No sampling is required. Rugged measuring unit is bolted into the production line, and feeds data to standard electronic indicating and recording circuit.

(45) KILNS, COOLERS, DRYERS: For 50 years *Traylor Engineering & Mfg. Co.*, one of the leaders in the advancement of rotary kilns, has engineered and developed many major improvements. Excellent photographs in bulletin 1115 show Traylor kilns, coolers, dryers, slakers, and other equipment in companies throughout the U. S. and the rest of the world.

(46) FLOTATION: *Denver Equipment Co.'s* bulletin M4-B70 is a full explanation of the flotation of a highly complex lead-zinc ore at Kootenay Base Metals Ltd. Details are given on construction and equipment costs, the flowsheet, mining methods and ore transport, power and water supply.

(47) DUST & FUME CONTROL: *Ducon Co.'s* UW-3 centrifugal wash collectors, used for controlling and reclaiming dust and fume, are subject of new booklet. Collectors combine exhauster and precipitator components in package units of 700 to 20,000-cfm capacity.

(48) PLASTIC PACKING: Information is available from the *Flexrock Co.* on an emergency packing claimed to be chemically inert and impervious to acids, alkalis, or solvents. Flexrock 403 is a Teflon plastic packing usable for valves, pumps, etc. where it is impractical to have preformed packing rings made to order.

(49) JOB STORIES: *LeTourneau-Westinghouse* has reprinted a series of on-the-job stories about "C" type Tournapulls. Pictured operations range across the country from North Carolina to Oregon.

(50) ROD MILLS: How to meet increasing demand for higher specification aggregates is discussed in an 8-page bulletin from *Allis-Chalmers Mfg. Co.* Bulletin describes characteristics of rod mills suitable for producing specification sand. It also carries dimensional layouts for mills with "Texrope" drive and with direct drive, along with dimension and capacity tables for each.

(51) STEEL BARGES: *Dravo Corp.* has a 28-page illustrated booklet describing all types of welded steel barges for river and harbor use. One

section is devoted to data and pictures of open hopper barges used to transport large tonnages of coal to operating areas and terminals along the inland and coastal waterways.

(52) CONCENTRATION: Design changes, said to mark the most significant improvements in wet gravity separation since *Deister Machine Co.* built its first table in 1913, are shown in a bulletin on the Plat-O ore concentrating table. Full details and latest improvements are given on the Triplex Plateau sand table, Single Plateau fine sand table, and the Single Plateau slime table.

(53) HAZARDOUS GASES: A tabulation issued by *Acme Protection Equipment Co.* shows 433 gases, fumes, mists, and dusts present in operations where a gas mask should be worn. Limits are given for determining safe working conditions.

(54) DACRON FILTERS: *National Filter Media Corp.* has information on a new filter cloth woven from Du Pont Dacron that shows excellent resistance to both acid and caustic attack at room temperature. It is strong, flex resistant, and stands up under severe abrasive conditions.

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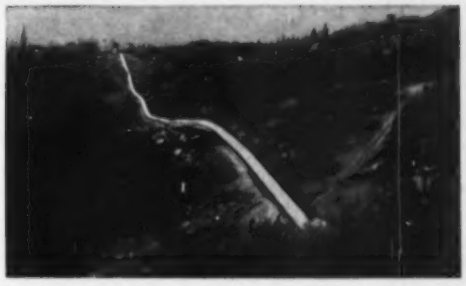
DOUBLE-DUTY S-A conveyor carries either lead-zinc or tungsten ore to transfer point (left center) where tungsten ore is shunted to tungsten mill at left and lead-zinc ore is dumped in underground storage pocket for delivery to mill in valley. Belt is loaded at right foreground by another S-A conveyor emerging from underground.



ALUMINUM "SNAKE" almost ½ mile long, houses S-A conveyor carrying lead-zinc ore to processing in valley beyond ridge.

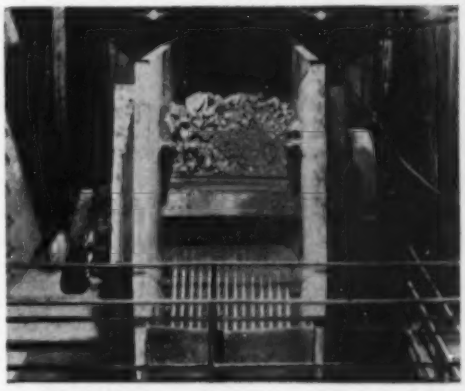
At Emerald Mine, B. C.

Conveying System Does Double Duty—Handles Both Tungsten and Lead-Zinc Ore...

A "sandwich" mine with layers of tungsten and lead-zinc ore created some real handling problems for the Canadian Exploration Company, Ltd. at their Salmo, B. C. installation. With both ores being mined simultaneously, handling by an existing aerial tramway and trucks proved far too expensive. S-A was called in to design and manufacture a system that would eliminate multiple handling while moving both types of ore efficiently.

The system installed and in operation since June, 1952, is an excellent sample of S-A's complete answer to a bulk handling problem. Two flights of the system (one underground) carry either tungsten or lead-zinc ore to a transfer point outside the mine. Here tungsten ore is shunted to a nearby processing mill while lead-zinc ore is dumped into an underground storage pocket. From here it is carried by conveyor flights down the mountain through a series of storage pockets to a mill in the valley. Feeders and screens as well as belt conveyors were built by S-A to fit exactly the requirements of the system.

When you look for ways to cut *your* ore handling costs, it will pay to call in S-A. Hundreds of plants have—with the result that they are now handling bulk materials at lowest cost per ton. Write for a free survey of your handling problem. Use coupon.



ALTERNATE FEED SYSTEM allows one conveying system to do the work of two! AMSCO Pan Feeder receives lead-zinc ore from chute at right, tungsten ore from chute at left.

SINCE 1901 S-A STEPHENS-ADAMSON MFG. CO.

STEPHENS-ADAMSON MFG. CO.
37 Ridgeway Avenue, Aurora, Illinois
Los Angeles, Calif., Belleville, Ontario

Engineering Division	Specialists in the design and manufacture of all types of bulk materials conveying systems.
Standard Products Division	A complete line of conveyor accessories including centrifugal loaders—car pullers—bin level controls—etc.
SealMaster Division	A complete line of industrial ball bearing units available in both standard and special housings.

STEPHENS-ADAMSON MFG. CO.
37 Ridgeway Avenue, Aurora, Illinois

Please have an S-A engineer make a free survey of my bulk material handling problem.

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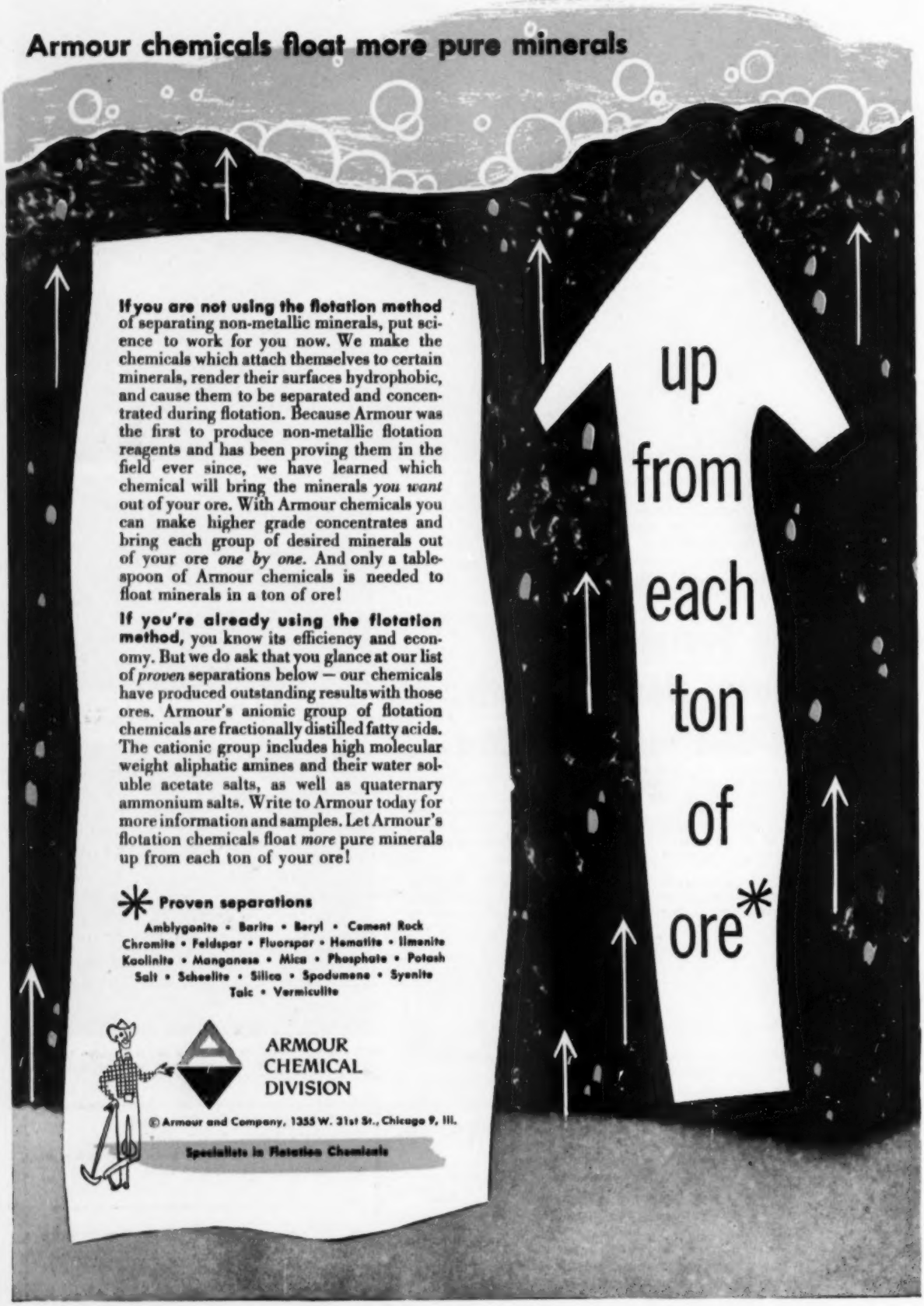
Armour chemicals float more pure minerals



If you are not using the flotation method of separating non-metallic minerals, put science to work for you now. We make the chemicals which attach themselves to certain minerals, render their surfaces hydrophobic, and cause them to be separated and concentrated during flotation. Because Armour was the first to produce non-metallic flotation reagents and has been proving them in the field ever since, we have learned which chemical will bring the minerals *you want* out of your ore. With Armour chemicals you can make higher grade concentrates and bring each group of desired minerals out of your ore *one by one*. And only a tablespoon of Armour chemicals is needed to float minerals in a ton of ore!

If you're already using the flotation method, you know its efficiency and economy. But we do ask that you glance at our list of *proven* separations below — our chemicals have produced outstanding results with those ores. Armour's anionic group of flotation chemicals are fractionally distilled fatty acids. The cationic group includes high molecular weight aliphatic amines and their water soluble acetate salts, as well as quaternary ammonium salts. Write to Armour today for more information and samples. Let Armour's flotation chemicals float *more* pure minerals up from each ton of your ore!

* **Proven separations**

Amblygonite • Barite • Beryl • Cement Rock
Chromite • Feldspar • Fluorspar • Hematite • Ilmenite
Kaolinite • Manganese • Mica • Phosphate • Potash
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Specialists in Flotation Chemicals

A BID FOR THE formation of an industry council of between 30 to 50 representatives was made by John G. Liebert, special assistant to Felix Wormser, Assistant Secretary of the Interior. The job of the council would be to make recommendations for "curing obvious illnesses" of the nation's metal producers, Mr. Liebert told the Wharton Subcommittee of the House Interior Committee.

Republic Steel Corp. has acquired what may prove to be the largest rutile deposit in the Western Hemisphere. The deposit is in southern Mexico in the province of Oaxaca, about 30 miles from Port Angelo on the Pacific Coast. Test drillings have been made and an adit driven almost 200 ft into the orebody. Transportation, despite rugged tropical conditions, poses no problem. Concentration of the titanium bearing ore will be done at the mine.

WALKER L. CISLER, president of Detroit Edison Co., told the Coal Convention of the American Mining Congress at Cincinnati, that "From the standpoint of electric power, adverse effects of atomic fuels on the coal industry seem to me to be far in the future, and very likely in any case to be offset by future changes in the energy situation."

SHERRITT GORDON HAD to raise some $8 million in the last few months because of higher than estimated plant costs and delays in completion of the Fort Saskatchewan plant. In addition to the new financing from sale of securities, an advance of up to $5 million was arranged with the U. S. Government on nickel concentrates.

White Pine copper mine in the Upper Michigan Peninsula is expected to be producing by the latter part of 1954, with limited output scheduled for November and December. Plans call for production of 75 million lb next year, but Morris La Croix, Copper Range Co. president, hopes the mark will be exceeded. Mr. La Croix also disclosed that uranium exploration on the White Pine property has proven fruitless, although the area contains, in addition to copper, small amounts of silver and gallium.

Coal operators held an emergency meeting in Chicago to map a recovery program. One of the questions was relations with the United Mine Workers, with some factions taking a stand on possibility of a knockdown fight with the UMW.

ALL LEHIGH NAVIGATION COAL CO. operations were shut down indefinitely, involving layoffs of more than 4000 men. W. J. Parton, company president, said the shutdowns were caused by "excessive operating losses."

THE 1953 SUPPLY of almost 9000 tons of new beryl was the largest in history, while domestic consumption was only 2662 tons. The U. S. imports about 90 pct of its beryl. Domestic mine shipments last year were about 750 tons.

The first shipment of alumina from Port Esquivel, Jamaica, some 11,000 tons, reached Kitimat recently. The first stage of the hydroelectric power and aluminum complex in British Columbia goes into operation this summer. Built by Aluminum Co. of Canada Ltd., the facility cost $275 million and took over 3 years to build.

AFTER "A LOT OF TROUBLE" Titanium Metals Corp. of America operations at Henderson, Nev., are in high gear, according to Clark W. King, executive vice president of Allegheny Ludlum Steel Corp. The Henderson plant is expected to reach a capacity of about 10 tons of titanium sponge per day by July. Titanium Metals is owned jointly by Allegheny Ludlum and National Lead Co.

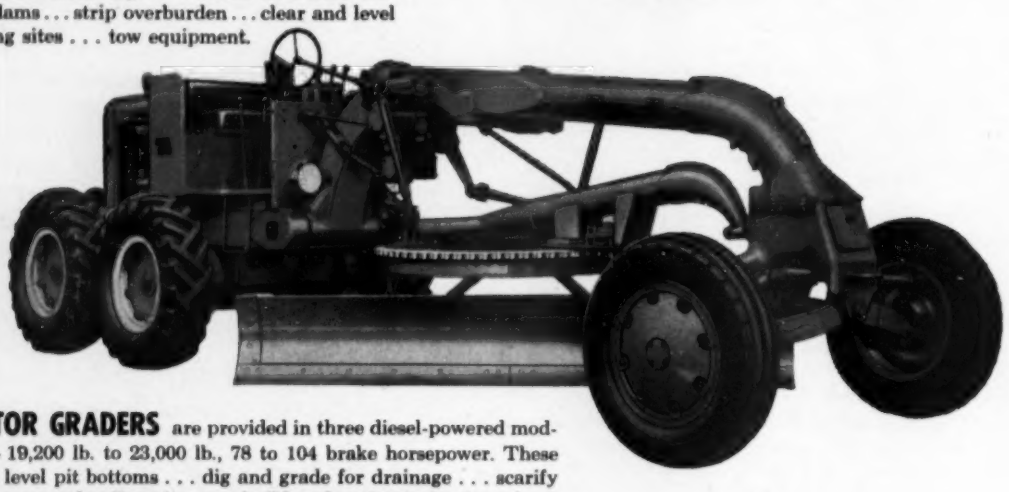
THE GALIGHER CO. of Salt Lake City has been awarded an AEC contract for the design of additional plant facilities at Monticello, Utah, to treat refractory uranium ores that cannot be processed in the existing Government plant. The AEC may advertise for bids on construction of the plant in the fall. The present Monticello plant is not equipped to extract uranium from the large tonnages of ore other than carnotite-roscoelite type accumulated by the commission.

HOW 6 BASIC ALLIS-CHALMERS MACHINES

mechanize and speed mining production

In today's competitive era, mining requires modern, versatile equipment that enables mine operators to increase output per man-hour and keep maintenance time to a minimum. To answer this need, Allis-Chalmers provides a line of newly designed heavy-duty equipment — 6 basic machines that mechanize and speed material moving and handling in many phases of mining production.

1 **CRAWLER TRACTORS.** Allis-Chalmers builds four sizes of heavy-duty diesel tractors: HD-5—10,500 lb., 40 drawbar hp.; HD-9—18,800 lb., 72 drawbar hp.; HD-15—27,850 lb., 109 drawbar hp. (hydraulic torque converter drive optional); HD-20 — 41,000 lb., 175 net engine hp. — hydraulic torque converter drive. With cable or hydraulic bulldozer blades they build access roads . . . maintain tailings dumps . . . clean up around shovels . . . cut drainage ditches . . . dig sludge basins and sluiceways . . . build reservoirs and pond dams . . . strip overburden . . . clear and level building sites . . . tow equipment.



2 **MOTOR GRADERS** are provided in three diesel-powered models — 19,200 lb. to 23,000 lb., 78 to 104 brake horsepower. These units level pit bottoms . . . dig and grade for drainage . . . scarify . . . prepare dragline sites . . . build and maintain haul roads. A gasoline-powered Model D Grader is also available. It handles routine road maintenance and light construction.

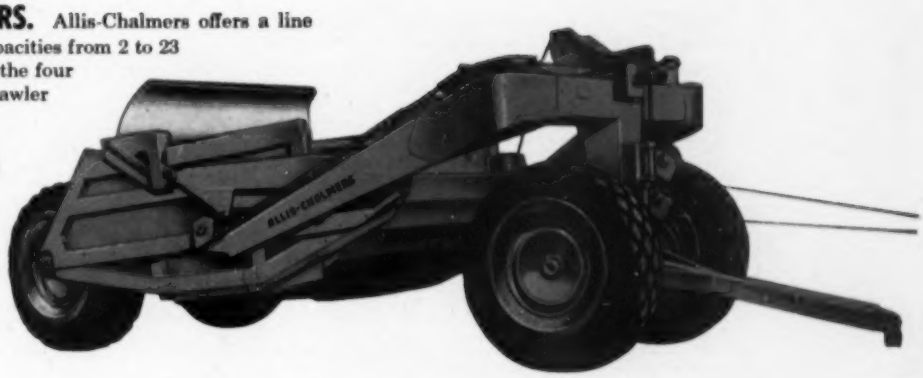
3 **TRACTOR SHOVELS** are available for all four sizes of Allis-Chalmers tractors. Standard bucket sizes range from one to four cubic yards —light materials up to seven cubic yards. These machines handle ore, tailings, coal and other bulk materials . . . clean up around shovels and hoppers and conveyors. Underground they load hauling units and excavate to reach new ore. Units are hydraulically controlled.

4

MOTOR SCRAPERS. The 18-yard (heaped) diesel-powered TS-300 Motor Scraper strips overburden, loads, hauls material from open pit . . . clears and levels for campsites and drill setups . . . levels and grades for access roads, building sites . . . hauls in supplies. A smaller 13-yard (heaped) TS-200 Motor Scraper is also available.

5

PULL-TYPE SCRAPERS. Allis-Chalmers offers a line of seven scrapers with capacities from 2 to 23 cubic yards. Matched to the four sizes of Allis-Chalmers crawler tractors, these tractor-scraper teams load and haul ore-bearing material . . . handle large-scale stripping jobs.



6

ROCK WAGON. The TR-200 Motor Wagon hauls tailings, sand, gravel, overburden and ore. Unit travels fast "off-road" with capacity loads . . . dumps clean every time with 18-ton hydraulically controlled rear-dump body. Double layer steel bottom with oak plank filler absorbs rock shock of overhead loading. A 22-ton bottom-dump Motor Wagon also available.

Write for catalogs or get the complete facts from your nearby Allis-Chalmers dealer.

ALLIS-CHALMERS

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THE NEW JERSEY ZINC COMPANY
obtains efficient performance from WEMCO S-H CLASSIFIERS

At the Austinville, Virginia, plant of The New Jersey Zinc Company, Wemco S-H Classifiers are being profitably used for wet classification control of the grind. Used in the primary grinding circuit, these Wemco units have proven efficient and economical in this producer's closed circuit grinding operations.

ONLY THE MODERN DESIGN OF WEMCO CLASSIFIERS OFFERS YOU ALL THESE FEATURES

Metallurgical Advantages

Greater raking capacity — S-H (Special-Helix) design employs advanced pitch and vari-pitch helices to provide up to 100% greater sand conveying capacity.

Sharper separation — controlled agitation and larger effective pool area means less undersize in the sands, less oversize in the overflow.

Greater overflow capacity — up to 25% more effective pool area than other types of units.

Balanced operation — between overflow and raking requirements with wide choice of tanks and spirals for correct performance under any condition.

Better drainage — spiral action squeezes out maximum amount of free moisture leaving drier sand for easier conveying and closed-circuiting.

Design Features

Up to 40% greater shaft strength — large diameter tubular shaft gives maximum protection against shutdowns.

Long-life wearing shoes — of tough, thick alloy with large cross-section; cuts replacement costs to as low as 4/100 of 1 cent per ton of sand raked.

Anti-friction bearings throughout — grit-proof lower bearings; gudgeon-type upper bearing mounted on hub of main bevel drive gear.

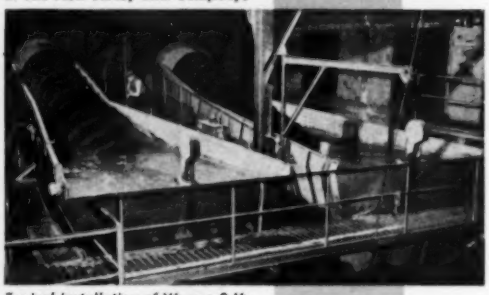
Simple hydraulic lifting device — operated by either hand or pump; affords protection against clogging or jamming; permits lifting of spiral to start machine without draining tank.

Efficient gear drive — employs special worm gear speed reducer; uses standard speed motor.

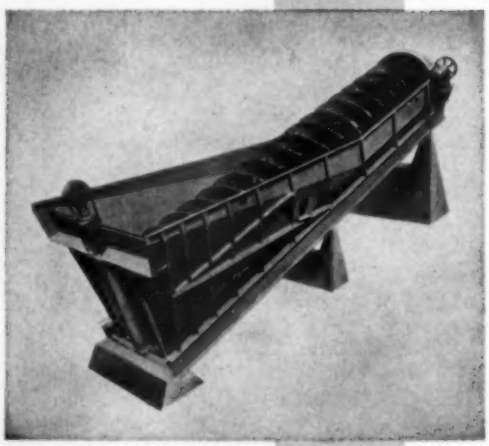
Send For Free Classifier Bulletin

This new, 20-page bulletin contains valuable, up-to-date information on wet classification principles and their application to Wemco S-H Classifier design. Write today for your free copy. No obligation.

78" Wemco S-H Classifier operating in closed circuit with grinding mill at The New Jersey Zinc Company.



Typical installation of Wemco S-H Classifiers in a closed grinding circuit.



84" diameter Wemco S-H Classifier.

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Drawpoint Loading Increases Production

Pictured above are two examples of drawpoint loading where costs have been reduced and safety increased.

In the upper picture, bad ground has been secured by concrete construction at the drawpoint. This type of ground is expensive to develop for chute and grizzly mining. In the inset picture above: Coarse block chunks are shown being easily loaded into cars but the same type rock would require more holes in the drilled round and more powder per hole to break it fine enough for the grizzly at the head of the chute.

Both mines have increased production. Both mines use EIMCOS exclusively, because they can depend on them for fast, efficient loading with a minimum of maintenance cost.

Production loading with Eimco RockerShovels will reduce your costs.

Cross section through limestone mine in California. Drawpoints are spaced on 25' centers on alternate sides of the haulageway. This spacing provides maximum control of drawing rock and continuous production.

B-37

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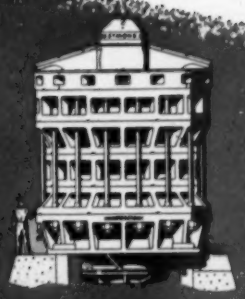
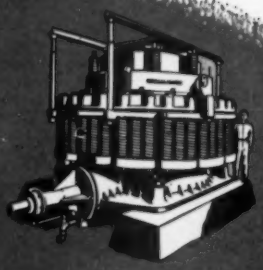
RELY ON

NORDBERG MACHINERY



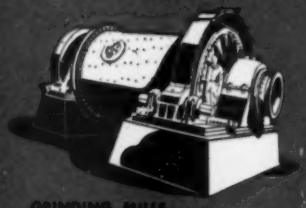
SYMONS PRIMARY GYRATORY CRUSHERS



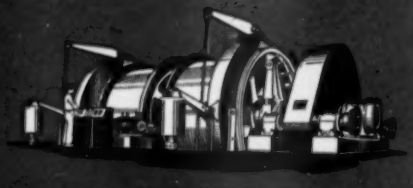
SYMONS CONE CRUSHERS

SYMONS VIBRATING SCREENS

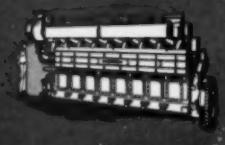
SYMONS VIBRATING GRIZZLIES



GRINDING MILLS



MINE HOISTS



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IT is highly significant that so many of the world's iron mining companies are using Nordberg Mining Machinery. This dependable machinery is designed and built to meet the specific needs of the Mining Industry. Nordberg manufactures SYMONS® Gyratory Crushers for primary breaking; SYMONS Standard and Short Head Cone Crushers for fine reduction crushing; SYMONS Vibrating Grizzlies and Screens for scalping and sizing; Grinding Mills for wet or dry grinding; Mine Hoists; and a complete line of Nordberg Diesel Engines to meet practically any stationary power requirement.

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M353

Unique Conveyor At New Pennsy Dock

Iron ore from South America, Africa, Labrador, and other foreign sources will travel over a rubber conveyor belt reinforced with high tensile strength steel cables at Pennsylvania Railroad's new $10 million ore pier on the Delaware River at Greenwich Point, Philadelphia.

The 93,000-lb 54-in. wide belt extends 1600 ft along a concrete pier and inshore to twin 600-ton capacity hoppers feeding ores into railroad cars. A two-belt system permits unloading two ore ships at one time at a rate of 3600 tph. When future expansion plans for the pier are completed, the belt system will be able to handle 10,800 tph from four ships simultaneously.

Ore is unloaded by 25-ton capacity buckets operating from cranes extending 72 ft on each side of the pier. Ore dropped by the buckets into a hopper then goes to the belts. The belt climbs 80 ft in a distance of 445 ft during the last leg of its route, scaling a 16° incline.

B. F. Goodrich engineers cut cable ends in a staggered pattern to splice the steel cable belt. Small tubular connectors were placed over the butted ends and then given a first light crimping. The partially made splice was then stressed to even the lengths of the cables and connectors given a final crimping, locking them to the cables. Rubber and fabric removed from the splice was then rebuilt around the cables and the splice cured under tension with a conventional vulcanizer.

The rubber conveyor belt at Pennsylvania Railroad's ore dock at Greenwich Point, Philadelphia, on the Delaware River. The B. F. Goodrich belt is one of the relatively few reinforced internally with high tensile steel cables. Ore handling system was designed and erected by Heyl & Patterson Inc.

New Sulphur Source

Victor Dykes, left, president of Texas International Sulphur Co., J. H. Pollard, center, company's chief engineer, and Joaquin Noriega, plant administrative manager, inspect the first slab of pure sulphur processed at the new plant at San Felipe, Baja California. The plant is the only one on the North American continent producing commercial sulphur from surface ore.

Montana Placer

Master Mining Co. of Chicago is working claims covering 3000 acres at 7000-ft elevation about 12 miles southwest of Gold Creek, Mont. One man with an Allis-Chalmers HD-9G diesel-powered crawler is able to produce about 600 cu yd of gold placer gravel during an 8-hr day in glacial wash-type terrain, sand, and boulders. A rock bucket attachment on the machine does the loading.

New Machine Literally Punches Away at Coal Seams . . . . . .

A two-fisted coal mining machine that throws 1800 punches every minute was unveiled by U. S. Steel Corp. at its Palmer mine, Uniontown, Pa. Invented by K. L. Konnerth, vice president of U. S. Steel's coal operations, the new machine minimizes, and in some cases eliminates blasting.

Electrically operated hammers mounted on a telescopic carriage vibrate against the coal face. Hydraulically operated cylinders raise and lower the hammer carriage 80 in., extend and retract hammers over a range of 34 in., and swing the carriage turntable to the left or right within the limits of the shear bars. The hammer is a cylinder upon which are assembled two pulsating-current electro-magnets. Laminated iron of the magnets is solidly welded to the cylinder to form a unit assembly. Piston or core is free to slide back and forth between two shears positioned at each end inside the cylinder.

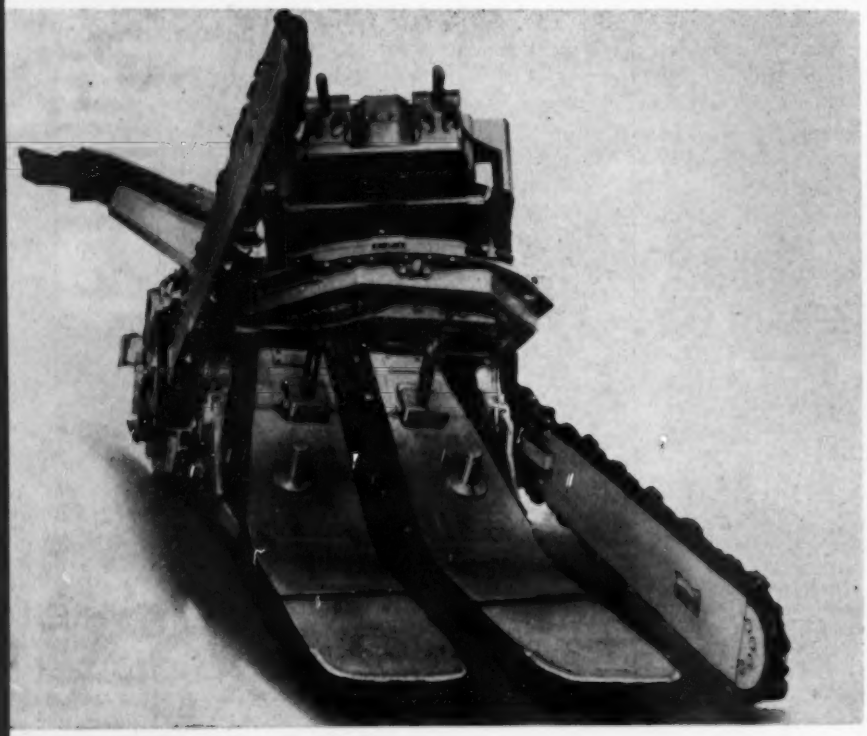
At the Karen mine, about 6 miles west of Brownsville, on the Monongahela, 12 machines working on a two-shift basis produced 4000 tpd by the end of 1953. The Karen mine was the scene of first successful operation of the Konnerth machine. Since then, some 28 units have been placed into operation in U. S. Steel coal mines in the Pittsburgh area.

U. S. Steel claims that the machine makes possible a greater proportion of lump coal and practically eliminates dust. The seams at Karen average 7 ft in thickness, and required small amounts of dynamite for loosening purposes. "Popping" as it is called, is used on the tougher mine workings. Eventually, all of U. S. Steel's coal mines will be equipped with the Konnerth machine.

Vibrating hammers pound away at a working face in the Palmer mine as the Konnerth mining machine goes to work. The hammers travel less than an inch and deliver 15 tons of force with each of the 1800 blows per min. All Palmer coal will soon be mined by the machines.

Built close to the ground, with rugged lines, the machine is only 54 in. high, but 6½ ft wide. Set low on either side of its front are twin, heavy-toothed chain cutters, looking much like locomotive cow catchers. The chain cutters slice 5-ft horizontal "kerfs" in the mine face at the floor level in preparation for the vibrating hammers. The kerfs are 6 in. wide and as deep as possible.

As they cut inwardly toward the



Standard model Konnerth machine is 6 ft 6 in. wide, 22 ft 6 in. long over the main body, with an additional 8-ft overhang of the rear conveyor, for a total overall length of 30 ft 6 in. Tramming height is 48 in. and maximum mining height is 80 in. The machine weighs about 46,000 lb.

Bottom bars and chains undercut the coal, slicing 5-ft horizontal kerfs in the mine face at floor level in preparation for the vibrating hammers. Kerfs are 6 in. wide and as deep as possible.

. . . Konnerth Miner Keeps Blasting at Minimum

center of the machine, the cutter bits of the twin chains also pick up falling coal, hauling it through the center of the machine to the rear, where it will be loaded.

Water spurts from nozzles in the cutter bars and settles dust as the kerf is cut. A water spray on either side of the machine lays the dust created by the vibrating hammers.

Power supply for the electric hammers is delivered by a nine-conductor cable from an explosion-tested motor-generator set consisting of a 15-hp dc motor directly coupled to a 28.8-kva, 160-v, 30-cycle generator and a 3-kw exciter for generator excitation. The power supply unit starting resistance and contactors for the dc motor on the machine are mounted on a portable 3-wheeled truck that can be parked in a breakthrough up to 550 ft from coal mining machine. Distance limit is dictated by cable length that can be handled between motor generator set and machine.

The machine is powered by a compound-wound, totally enclosed, fan-cooled 70-hp dc motor. Cutting, tramming, and conveying are mechanically performed and controlled by hydraulically operated disk clutches. Hydraulic power for positioning operations is supplied by pumps through an independent hydraulic system.

Stroke of the hammers is governed by a core stop at the back end of the cylinder and a vibrating tool shank in a bushing at the other end. A preloaded coil spring holds the core stop in position and absorbs the piston's return stroke energy. Another preloaded coil spring is set against the spring seat on the tool end and limits the stroke when the vibrating tool is operating in free air and not against the coal face.

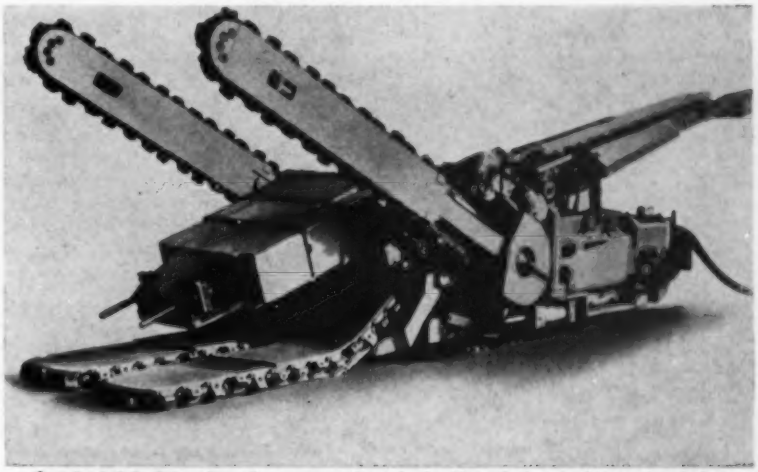
In operation, each coil is alternately excited by single-phase alternating current through an oil-immersed selenium rectifier. This produces a pulsating direct current that is in step with the frequency of the ac supply. The piston is reciprocated, striking the tool at one end and the spring-loaded core stop at the other. Difference between overall length of the piston and distance between the two stops establishes the length of the stroke. Normal power supply to the rectifier must be 150 v, 30 cycle. Overall input to the hammer is 80 to 90 amp ac.

Number of piston strokes is set by the 30 cycle frequency when rectified, giving 30x2x60 or 3600 total reciprocations; and since only half this number strike the shank of the tool, the cyclic speed is 1800 blows per min. The force of each blow is approximately 30,000 lb.

Bottom bars and chains undercut the coal and convey it from mine floor to discharge conveyor. Coal is conveyed by cutter chains and bits in the 11-in. space between the bars. The 43 blocks making up each chain are connected with universals so that the chain can follow the vertical angle in the bars. Standard 9-ft 9-in. shear bars mounted on both sides of the machine swing independently through vertical arcs.

Coal is discharged by combination conveyor-cutter chains into a hopper located in the center of the main body of the machine. The coal is moved from hopper to shuttle car by a single-chain, flight-type conveyor, traveling at 290 fpm. The chain operates in a conveyor boom that extends 8 ft beyond the rear bumper of the coal mining machine and can swing 65° to either side of center. The conveyor can be elevated 38 in. above the horizontal at discharge end.

With the Konnerth machine, three or four men can operate a mine section. Aside from the machine operator, crew members have no specific duties. They are responsible for all preparations in the working area.



Standard 9-ft 9-in. shear bars mounted on both sides of the machine swing independently through vertical arcs from top to bottom. The flight type conveyor in the rear moves coal from hopper at center of machine to shuttle cars.

The Konnerth miner moves into position easily at a working face. The man operating the machine learned his mining with a pick, but has easily mastered the techniques involved in the new miner.

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IRON ORE—An adaptation of the Joy Air Leg for drilling soft ores in the Iron Country is this model equipped with the Joy H-37 auger drill. Versatility of the Joy combination is shown here in its use as a stoper, an arrangement made possible by mounting in such a way that the drill and leg may be placed in almost parallel positions.

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NICKEL—*This driller shows "one-hand" operation of the Joy Air Leg and LM-47 as he drills face holes in a nickel mine.*

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BRANCH OFFICES AND WAREHOUSES THROUGHOUT NORTH AMERICA

BLM Survey Report Guides Administration

As a result of the survey started last October to study organization and operations of the U. S. Bureau of Land Management, the six regional offices of the BLM are being replaced by three new area headquarters.

The action is the first taken on the report. The work of the survey team has been approved by Secretary of the Interior Douglas McKay, Undersecretary Ralph A. Tudor, and Assistant Secretary Orme Lewis. Edward Woozley, Director, Bureau of Land Management, has been instructed to carry out the report's recommendations.

The three new areas and their directors are: Area 1, covering California, Oregon, and Washington, James F. Doyle, Portland; Area 2, Arizona, Idaho, Nevada, and Utah, H. Byron Mock, Salt Lake City; and Area 3, Colorado, Montana, New Mexico, Wyoming, and other states not served by the Washington office, Westal B. Wallace, Denver.

In the report, Bureau functions were defined as: service functions, including cadastral surveying and keeping of public land records; disposal activities, covered by mining laws, public land laws, and mineral leasing laws; and management duties, with respect to forests, under the Oregon & California Lands Act, the range, under the Taylor Grazing Act, and public lands generally pending final disposal.

The survey team reports that: "Of the three major functions of the bureau, that of disposal has been the most neglected. Evidence of this was found in the very large number of applications for lands and minerals pending before the bureau on which no action has been taken."

The survey report notes that the Mining Act of 1872, with its attendant court decisions, defines a valid mineral discovery and provides for granting of mineral claim patents. In law administration, the Bureau of Land Management exercises a wide field of discretionary power in defining closely validity discovery.

"There are many who feel that these definitions in recent years have been restrictive to the point where they defeat rather than encourage the intent of the law.

"The requirement of the law 'that the substance exists in such quantity as to justify a prudent man in expending labor and capital in the effort to obtain it' has been, in the administration of the act, interpreted 'that the land is more valuable for the purposes of removing and marketing the substance than for any other purpose' and 'that the removal and marketing will yield a profit.' There certainly seems to be considerable difference in the requirement and application of the law."

Joy Announces Improvement on Extensible Belt

A long distance continuous haulage system providing uninterrupted transportation for continuous miners driving rooms and entries to 1000 ft, including breakthroughs and pillar extraction, has been announced by Joy Mfg. Co.

The system is in reality the first production model of the Joy Extensible belt conveyor first shown in 1953, with the addition of a new bridge conveyor—a flexible connecting link between the ExB and the miner—and the new, two-bearing Joy Limberoller.

The ExB consists of two main units: a crawler mounted driving section with a tandem drive and multiple-loop takeup, automatically tensioned, with storage capacity of 100 ft of belt; and a tail section, also crawler mounted, that moves with the miner and extends the conveyor.

Lightweight, portable idler stands are added to the moving belt as needed. The ExB extends or retracts for 50 ft while operating under full load. New sections of belt, 100 ft in length, can be added in about 5 min allowing an additional 50-ft advance. Belt tension, alignment, and slippage control are automatic.

The one-piece bridge conveyor, with self-powered belt drive, is flexibly suspended from the discharge end of the miner to permit a swing of 75° to either side, and is flexibly supported at its discharge end by a track-mounted carriage with 10-ft travel on the tail section of the ExB to permit a similar 75° swing and a telescoping action at this point.

Thus, the bridge conveyor is automatically positioned between the continuous material flow.

The ExB can be dismantled at the worked-out location, moved and set up again in about 1¾ hr.

The Joy extensible belt, complete unit together with lightweight, portable conveyor sections, has only three motors. In lower picture, the conveyor is at work with a Joy continuous miner in a 16-ft wide room. Conveyor extends 1000 ft and moves 50 ft while loaded or empty.

Jones & Laughlin to Option Canadian Ore Property

Jones & Laughlin Steel Corp. has 2 years of exploration and research ahead of it on land 6 miles from Kirkland Lake, Ont., to be optioned from Gulf Oil Corp.

The proposed agreement provides that the steel firm may lease the land at the end of the 2-year option period, should exploration results prove encouraging. The iron ore deposit, located in Boston Township, is a magnetic taconite ore of Keewatin type, report J&L geologists.

Iron bearing rock occurs interbedded with greenstones. Tonnage and grade of the taconite are unknown, J&L geologists say, but it is expected that the property may contain reserves of 150 million tons of open pit magnetic taconite ore.

During the option period, the research will attempt to determine grade, tonnage, and concentrating characteristics of the Boston Township deposit. The steel corporation emphasizes that the proposed optioning of the site does not mean immediate large scale development. It is expected that even after option completion much work would be necessary before start of production.

If the agreement is actually made, exploration of the area is planned for this fall. Detailed drilling is planned after the option period to establish pit limits. Other activities would include development of a mining plan, research pilot plant tests to finalize a flow sheet for ore beneficiation, design and construction of a beneficiation plant, and development of the orebody for production.

Negotiations for the option have been underway for some time. Final agreement was dependent on outcome of negotiations for establishment of a competitive freight rate between the Canadian deposit and J&L's Pittsburgh steel plants.

A competitive freight rate has been reached through the cooperation of the Ontario Northland, Canadian National, New York Central, and Pittsburgh & Lake Erie railroads. All four will take part in moving the Kirkland Lake ore to Pittsburgh.

The new deposit was discovered through an airborne magnetometer survey. Dominion Gulf, Gulf Oil Corp. subsidiary, staked claims on the northern half of the deposit, and later obtained claims previously staked on the southern half. In 1951 Dominion carried out detail surface geological and geophysical investigations. A small diamond drilling program was completed in 1952.

Kirkland Lake area in Ontario where Jones & Laughlin is optioning iron ore deposit, and its relation to Pittsburgh steel mills.

J&L has been producing a large tonnage of ore from low grade property at Benson Mines, New York.

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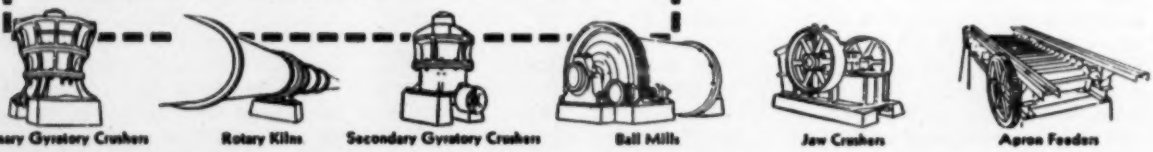

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Cyanamid REAGENT NEWS

Mineral Dressing Notes #20

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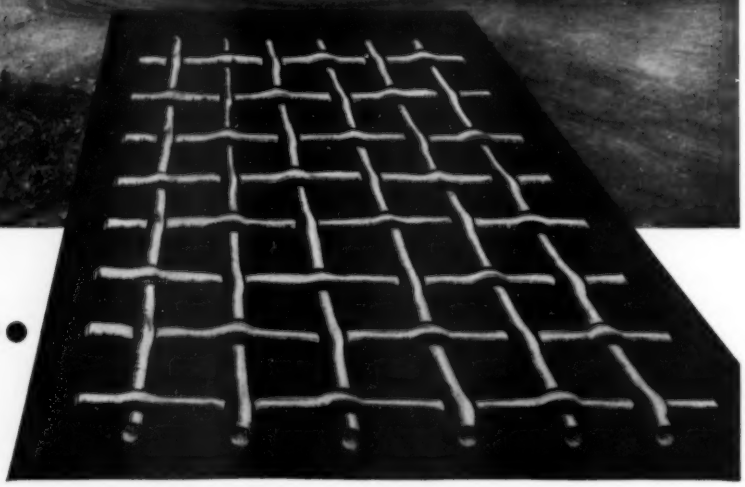

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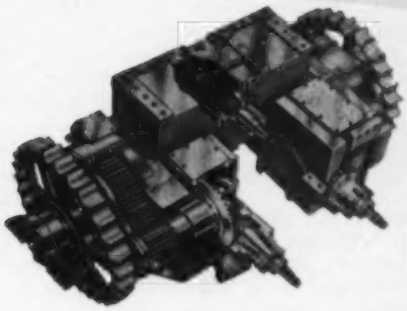

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TIMES have changed for the mining industry and attitudes must change also if the industry is to survive in a way that will be of most benefit to the nation. That about sums up what Miles P. Romney, manager, Utah Mining Assn., told the 36th Annual Meeting of the American Zinc Institute at St. Louis. "The degree of public understanding and approval the mining industry has attained is the measure of its public relations," Mr. Romney said.

He emphasized the changes that have taken place in the minerals industry through periods of depression, war, and post-war readjustment. These changes, Mr. Romney feels, have left the public with "attitudes detrimental to the mining industry." Right now, free enterprise and personal freedom are engaged in a world-wide struggle with the principles of statism and slavery. Thus, he maintains, it is imperative that the mining industry, for its own good and for the good of the nation, take an active part in "insuring the continuance of free enterprise."

The principal problem of the industry is to "acquaint the public with the fact that mining can be maintained as a healthy, progressive industry only under free enterprise principles—principles which encourage risk investment in the prospecting, exploratory, and long-range development phases of the mining cycle."

He also spoke of metamorphosis of the industry from a framework where it was unburdened by excessive taxation and was "more or less" autonomous in the communities where it operated. The mining industry has had a tough public relations problem dumped into its lap. "Acceptance of the situation and adjustment of the problem has been slow and inadequate."

The necessity of encouraging mining, its vital role in the local and national economy, the part it plays in national defense, and the contributions it makes to a higher standard of living must be gotten across to the public, Mr. Romney says. The chances for contact are many: stockholders, employees, suppliers, and citizens of the community are fertile areas for proper public relations.

"The job will not be done with one letter, one poster, or one talk. Management must first realize that it is a long-range program; that it will be slow in results, but vital to survival."

◆◆◆◆◆◆

WHEN Edward J. Chalmers approached New York State Land Office officials for a permit to make test drillings on certain land they did a double-take. Mr. Chalmers had been taking Geiger counter readings on state-owned Camp Smith, north of Peekskill. Camp Smith is used by the National Guard for live ammunition firing of mortars and machine guns.

Mr. Chalmers, however, took his surveys in area surrounding the camp, not actually in it. But he feels that results indicate that commercial uranium deposits may be within the camp limits. The National Guard has posted sentries around the camp area to keep uranium-happy amateurs from getting in the way of any stray metal.

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THE U. S., a nation of specialists, is developing another kind of specialist who bursts into flower about the time of an economic change. He is the predictor, the estimator, and the summarizer. Flowing in an almost endless stream across desks throughout the nation are various reports on the health, wealth, sickness, and imminent demise of the country. Each report sounds a note slightly different than its brother.

Business is up, it's down, activity slackens but remains high, and only time will tell are phrases the reports use as stock in trade. Many executives agree that to read only a small sampling of the reports would cost them a great deal of valuable time. Most agree that one way or the other, the nation will survive quite well through application of basically sound economic measures applied by private enterprise. One report, typically impressive, properly cautious, and decently optimistic, sounded somewhat sophomoric when stacked against headlines appearing the morning it was received.

◆◆◆◆◆◆

MINERAL production in the Province of Quebec was worth only about $2.5 million at the turn of the century. By 1925 it had increased to $25 million and today approaches a quarter of a billion dollars. Jean Paul Drolet, chief, Technical Information, Quebec Dept. of Mines, summed up the province's mineral position in his address to the annual meeting of the Engineering Institute of Canada at the Chateau Frontenac, Quebec.

Not too long ago, according to Mr. Drolet, Quebec mining was almost completely devoted to industrial minerals and building materials. Metals and industrial minerals each represent 40 pct of present mineral output while building materials account for the remaining 20 pct. Mr. Drolet predicts that "mineral production will show a further 50 pct increase in value in the next 5 years."

Iron Ore Co. of Canada is expected to ship its first million tons of ore from Sept Iles this year, with an increase to 10 million tons annually scheduled for 1957. Until the St. Lawrence Seaway is completed most of this ore will go to Philadelphia by sea and then to inland steel mills.

In addition to a hydroelectric power plant at Menihek that supplies electricity for mine operations, another new plant shared with Gulf Power & Paper Co. will supply power for car dumping equipment and the ship loading dock at Sept Iles.

The world's largest and richest ilmenite deposit is being mined at Allard Lake, 400 miles east of Quebec City. The ore is shipped by rail to Havre St. Pierre and transferred by boat to Sorel, where Que-

bec Iron & Titanium Corp. has an electric smelter to treat the ore. Some 300,000 tons of ore were treated in 1953 to produce about 100,000 tons of iron and 125,000 tons of titanium oxide slag.

In the eastern part of the Gaspé Peninsula, Gaspé Copper Mines Ltd. is developing ore reserves estimated to contain millions of tons of pure copper. A concentrator with the largest initial milling capacity ever installed in Canada is being constructed, along with a smelter to produce 125 tons of metallic copper daily.

Hydro power sites capable of supplying the amount of energy needed are rare in Gaspé. Power will be transmitted through marine cables 33 miles across the Gulf of St. Lawrence from Quebec Hydro's Bersimis power project on the north shore.

Asbestos, nearly a million tons of it, is being shipped annually from the Eastern Township mines. Johns-Manville's Jeffrey mine is currently being converted to an underground operation. MINING ENGINEERING, May 1954, describes the mining method being employed. Asbestos Corp. is developing a new mine and treatment plant, and a large new plant will replace the old Johnson's Ltd. mill. Another project is scheduled to place the United Asbestos Corp.'s property back in production with a new 4000 tpd capacity. Black Lake will be dredged to remove some 30 million cu yd of clay to reach asbestos deposits.

Half a billion lb of aluminum is turned out annually by smelters at Arvida, Isle Maligne, Shawinigan, and Beauharnois from British Guiana bauxite.

◆◆◆◆◆◆

THE understanding and reporting of scientific achievement will be one of the most vital tasks facing the newspaper reporter of the future, an eastern university journalism professor told his students several years ago. The statement, envisioning somewhat of a departure from the idealized front page type character conjured up by the student group, was greeted with something less than enthusiasm.

But with more and more space devoted to news stories emanating from physicists, metallurgists, electronic engineers, and mining men, many of those students have most probably changed their ideas. A lot of them are certainly engaged in some form of technical journalism.

The accurate, concise reporting of scientific progress has become one of the major problems of editorial work. Newspapermen have formed an association of science reporters. *Editor & Publisher*, magazine of the newspaper business, devotes increasing amounts of space to science reporting problems.

When Rudolf Flesch was called in by the Associated Press to redesign writing techniques his problem was simple in one sense, and quite difficult in another. Making newspaper *language* readable could be accomplished through obvious changes. Adjusting attitudes was another matter. Newspapers can popularize to the extent that the "Kansas City Milkman" and the American housewife will understand. Translation of material in technical journals into newspaper simplicity is somewhat less simple.

Accurate reporting, clear writing, and tight prose are basic journalistic tools, but before they can be used the journalist must understand his subject. Recognizing this, a joint session is planned on the role of the journalist in accurately communicating scientific material to the public at the Nuclear Engineering Congress, University of Michigan, June 20 to 25. The session will be sponsored by the school's Dept. of Journalism.

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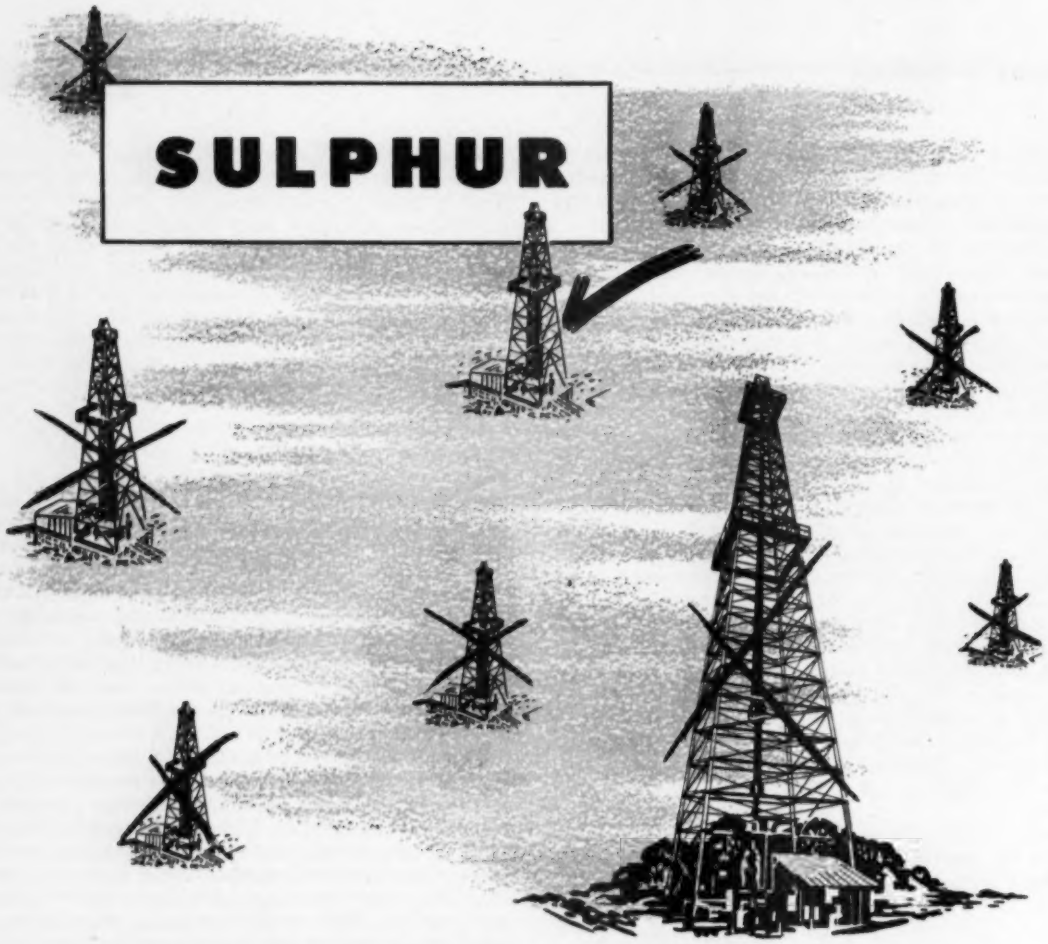
MEN have long sought to obtain power directly from the sun. The dream came closer to reality when Bell Telephone Laboratories disclosed that it had developed a solar battery that converts the sun's rays into electricity. The battery is simple looking, and is composed of 2½ x ½ in. silicon wafers imbedded in a transparent plate. But its history can be traced back to at least the first decade of the 20th century.

The battery has an efficiency of 6 pct, according to Bell, and compares favorably with steam and gasoline engines. Other photoelectric devices have never been rated higher than 1 pct. Improved techniques are expected to increase efficiency. Right now, the battery can operate a walkie-talkie, transmit voices over telephone wires, and run a transistor radio carrying music. With no moving parts and nothing to wear out, indefinite life expectancy for the battery is foreseen.

The solar battery is still in the experimental stage, but it may get practical application soon. A rural telephone line is under trial at Americus, Ga., using Bell-invented transistors. It is hoped that the line will prove possible greatly increased rural service without additional wires. The solar battery could be used, according to Bell, at amplifier stations along the line. Solar batteries may also be employed as power supply for mobile, low-power equipment.

Developed by three men—G. L. Pearson, C. S. Fuller, and D. M. Chapin—the solar battery depends on a new technique for the controlled introduction of a foreign element into a microscopic layer near the surface of the thin slice of silicon. C. S. Fuller developed the process which consists of simply heating the semiconductor wafer in the presence of a suitable impurity vapor. This provides essentially a p-n junction, which when built into germanium single crystal is the basis for the junction transistor. (William Shockley covered p-n junctions in JOURNAL OF METALS, August 1952). According to Bell, the impurities reach a depth of less than one ten thousandth inch.

While some anticipate rooftops covered with silicon strips supplying enough power to light homes, Bell scientists are loath to make predictions. The experimental battery solar strips linked together deliver power at the rate of 50 w per sq yd of surface. It would take about 100 sq ft of silicon wafer surface to keep a 100-w lamp burning all day.



. . . producing Dome Sulphur is a *Chancey* business

"What is the cost?," is a constant and persistent query in the minds of managers whether operating a manufacturing plant or a mine.

When erecting a manufacturing plant the manager selects his location in regard to transportation of raw materials to the plant and distribution of the finished goods. On the other hand, a mine is found where nature has placed the ore and production must be in that locality.

In the case of production of sulphur by the Frasch Process, the ore lies 500 to 2500 feet below the earth's surface where nature made the underground formation. No engineer can see producing conditions.

Because of variations in formations, some sulphur mines produce efficiently and cheaply. Cost of production and marketing compared with the price determines whether the sulphur is commercially available.

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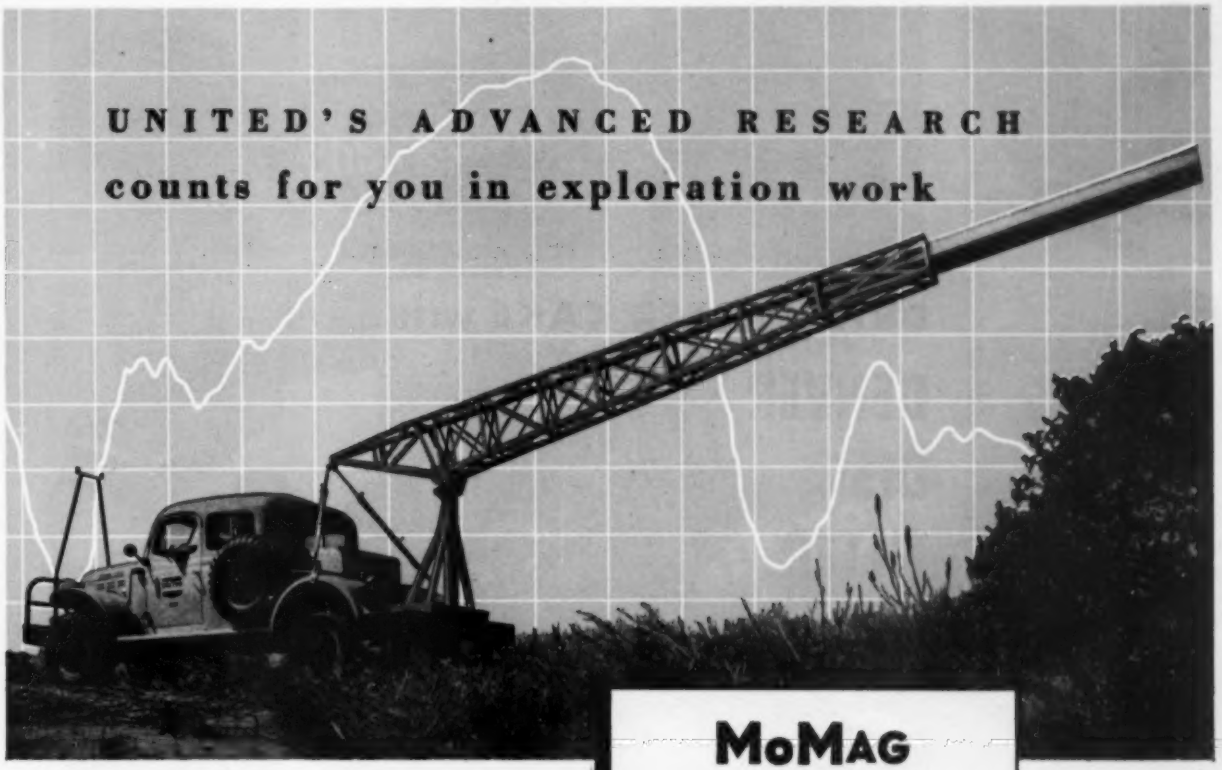

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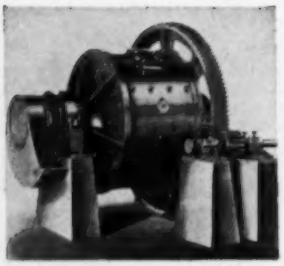

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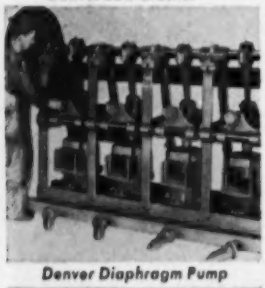
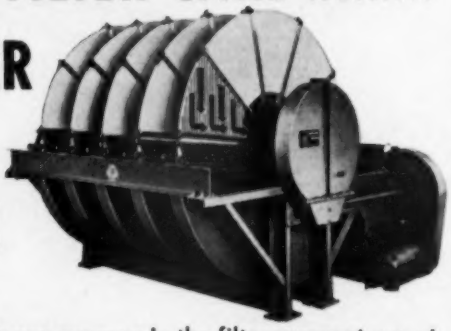


Denver Diaphragm Pump

DRIER FILTER CAKE WITH...

DENVER DISC FILTER



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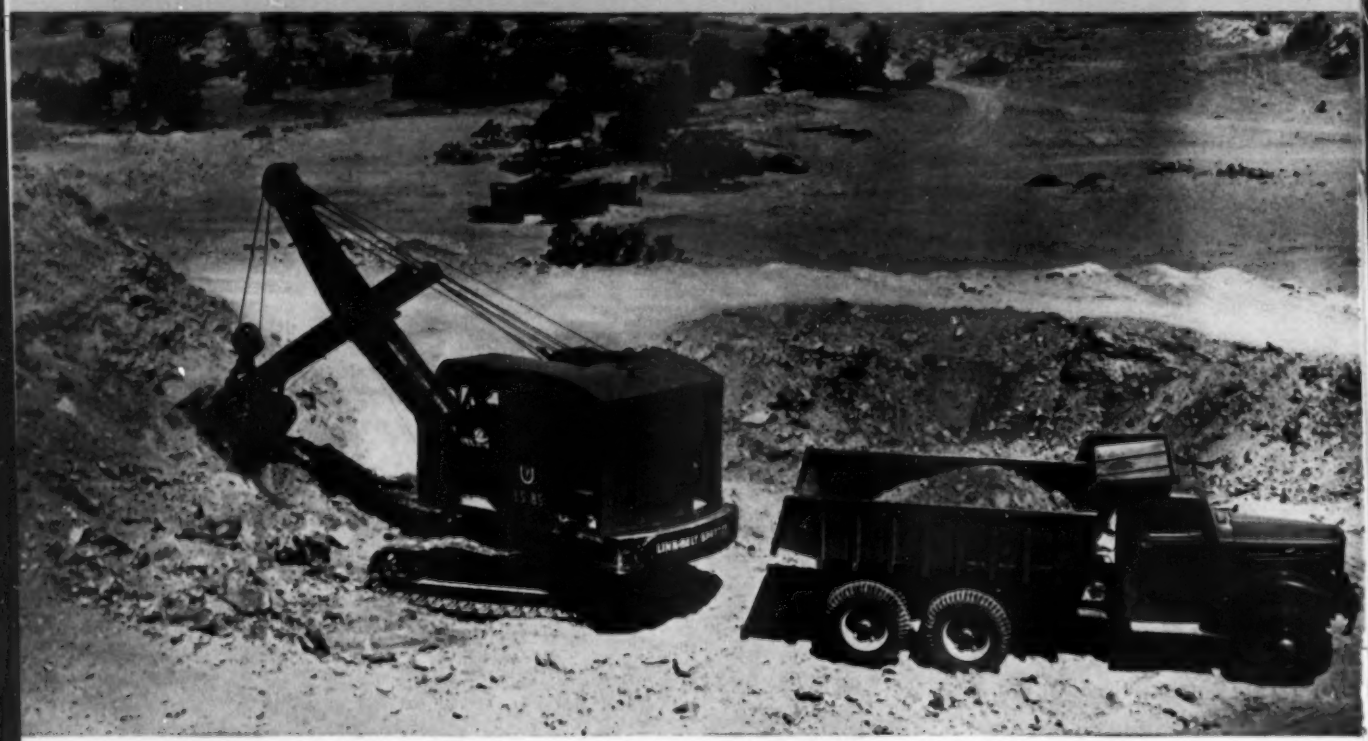

High up on the Continental Divide, this ¾-yard Link-Belt Speeder loads crude uranium ore for Haystack Mountain Development Co. In eight months of week-in, week-out operation through climatic extremes and abrasive dust, its Caterpillar D318 Diesel Engine has needed *no repairs*. Ruggedness and freedom from down time are vital in this remote area, about 15 miles northeast of Prewitt, N. M.

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Drift of Things

AN editorial by E. L. Lee in the May issue of *General Electric Review* led to considerable thought about our own organization. Here are portions of his piece which was entitled "The Engineer—and His Professional Society."

"The engineer is a builder. And not only does he build the products of industry, he builds engineering societies—strong, active organizations of great power. In them he hears his associates tell of new advances in engineering, new systems, new products, new horizons. And he is a much better engineer for those associations than he would be without them.

"The freedom of telling of our accomplishments has been a key to unlock the door to new vistas. It is the introduction to new ideas, to new accomplishments, to new friendships. To walk and talk with one's fellow engineers is to feel the thrill of the profession, to experience the great motivating power of achievement. Every engineer can have the thrill of this experience."

And it is a thrill to see a Local Section committee go into action to provide this medium for technologists of the mineral industry.

On April 24, the Adirondack Section, chairmanned by Paul W. Allen, met at Saranac Lake to perfect plans for the 1954 Industrial Minerals Div. fall meeting. Nine section members met after the dinner meeting and worked out meeting details. Not for the technical program, but the onerous details such as registration, housing, publicity, and finances required to care for the group that will carry on with the rest of the program. Although this is sometimes overlooked, energetic groups like this build up the AIME and carry it forward. Working behind the scenes is not a publicly acknowledged effort, but it constitutes the groundwork upon which a professional society is founded.

Now, let's establish the relation of this data to all other functions of the Institute. The first item in the certificate of incorporation states:

"That the American Institute of Mining Engineers is an unincorporated association organized and existing with the object of promoting the arts and sciences connected with the economic production of the useful minerals and metals and the welfare of those employed in these industries by means of meetings for social intercourse and the reading and discussion of professional papers, and to circulate by means of publications among its members and associates the information thus obtained."

This establishes the entire operation. First, the Institute has to publish the material presented to and accepted by its members. This is the ultimate aim of a group such as this, because the publications supersede all other activity, as a medium for forwarding "the object of promoting the arts and sciences . . ."

Here it becomes clear, that meetings are necessary to fulfill the needs of publications. Meetings benefit only a percentage of the Institute membership directly, but indirectly they act as a protective league for members not attending by screening the information presented prior to publication. Almost all AIME members attend a meeting of some type and perform this service for all other members.

Going back to the discussion of the Planning Committee of the Industrial Minerals Div. you can see that its activity is not as isolated as it might seem. This planning will affect and enhance the Institute from the Adirondack Section through the entire structure, arriving at the endpoint—publications.

The reins held by each member carry more weight than is sometimes realized. No part of the organization can be divorced or set aside. A member in Southern Arizona at a local meeting can conceivably sway the course of the society simply by discussing a paper presented to the group. Admittedly the change would be small but the sum of such changes establishes the final course.

In the Feb. 26, 1954, edition of the *Peruvian Times*, the lamentable death of Fernando Fuchs was announced (*see Obituaries p. 656*). Here was a distinguished person, whose untiring efforts were effective in the establishment of an AIME Local Section in Lima, Peru. Quoting from the *Times* article, "A member of the American Institute of Mining and Metallurgical Engineers for more than 50 years, Mr. Fuchs was the guest of honor at a dinner dance given by the Lima, Peru, Local Section of the AIME. . . . At this entertainment he was presented with a silver plate and a special scroll signed by the AIME members in Peru." This event also celebrated the first anniversary of the Lima, Peru, Local Section.

Now, this newly organized group in Peru, which is only 2 years old, has offered to be host to the AIME for a regional meeting in 1956. Wherever the 1956 meeting does take place, it will take place because of such men as Mr. Fuchs whose lives are not only important to their own countries, but to the entire Institute membership.

PETROLEUM refiners are doing miracles, as any reader of the gasoline advertisements must know, or at least has been told. Not only technology but labor problems are in the field of the latest refining equipment. In the *New York Herald Tribune* of May 10 we read of what the Standard Oil Development Co. has done in one of the new petroleum refining techniques known as *hydrofining*. Nineteen units have been installed, are under construction, or planned. "A wide variety of products, from gasoline to wages, will be upgraded in these units," says the *Herald Tribune*.—E. H. R.

SOMETIME ago we overheard the story of the "self-made" man who was expounding his virtues to a polite elderly lady at a social gathering. He repeatedly described his wordly successes prefacing each item of accomplishment by the fact that he was "self-made." The lady grew tired of the story and the repetition, but being polite, she reserved comment until the banal remarks became irritating. She finally explained that "I am happy to hear that you are 'self-made', because I am sure that the Almighty wouldn't want to take credit for the results."

Charles M. Cooley

Cost Factors in the Utilization of Foreign Bauxite to Make Aluminum

Increasing use, if not dependence, on foreign raw materials today sharpens the importance of transportation as a cost factor throughout the mineral industry. And, the detailed breakdown of unit transportation costs here is of broad value for all mineral commodities, not just for bauxite.

by Arthur F. Johnson

THE principal costs of making a pound of aluminum are for 9 kw-hr of electricity and for 1.9 lb of the oxide (Al_2O_3) called alumina. A pound of alumina is made by digesting 2 or 3 lb of bauxite in hot caustic solutions, settling and filtering out the oxides of silicon, iron, and titanium and precipitating and calcining the Al_2O_3 as a pure, white powder. The cost of foreign bauxite delivered at an alumina plant in the U.S. may equal or exceed the cost of its chemical treatment to make alumina.

Some of the principal factors affecting costs in the utilization of foreign bauxites are: transportation from mine to market, mineralogical and physical composition of the bauxite, thickness of the bauxite beds and their clay and forest overburden, amenability of the bauxite to beneficiation and to caustic extraction of the alumina, and lastly size of bauxite deposits and rate of mining employed.

Most foreign bauxite used in North America is mined in British or Dutch Guiana or Jamaica. In Jamaica in 1952, 404,755 LT of bauxite were mined by three producers (Aluminum Ltd., Reynolds, and Kaiser) and 264,988 LT imported into U.S. apparently all for Reynolds plants. About 1.3 to 1.6 million tons were imported into the U.S. by Kaiser and Reynolds in 1953. Exports of alumina from Jamaica to Norway in the first quarter of 1953 were about 5000 tons with declared value of about $363,000.

Exports of bauxite to the U.S. from Surinam in 1952 were 3,109,375 LT and apparently were about the same in 1953. In 1951 about 80 pct was Alcoa bauxite production and 20 pct Billiton production. At the end of 1951 Alcoa's Moengo Hill mine was exhausted after producing 10.25 million tons in 25 years and a new mine 9 miles east was being opened. In British Guiana the Demerara Bauxite Co. (Alcan) exported 1,968,190 tons of dried bauxite in 1952.

Transportation Cost and Aluminum Cost

Transportation from mine to market is a major cost component. It becomes most important considering that the ultimate market center for fabricated aluminum metal in the U.S. probably lies in Indiana or Ohio, and that the bauxite from the time it is stripped and mined is merely being processed in transit. Bauxite may be beneficiated in Surinam, chemically treated to make alumina in Mobile, electrolytically reduced to make the metal aluminum with cheaply sold hydropower in Washington, and rolled into sheet at Davenport, Iowa, before final shipment to destination in the U.S. market centers further east. The transportation route from mine to market may cover 7000 miles or more. Rather than analyze any one particular set of costs, if a certain bauxite and the metal made from it travels a particular route such as that given above, it was chosen to break transportation costs down to costs per ton mile by truck, ship, and railroad since this enables one to make comparative estimates with various routings.

The figure (p. 600) is a graphic comparison of the costs per ton mile vs length of haul. The tables show approximate cost range of mining and beneficiating bauxite, making alumina, and reducing it to aluminum pig. Total costs for each type of operation are equal to the operating costs shown plus a percentage of the investment cost to provide for amortization and interest. This might amount to 8 pct when normal amortization is 20 years. An aluminum producer's overall cost consists of those shown in the first table plus the costs of transportation from one type of plant to another. To save freight on alumina, reduction plants have been built on the Gulf Coast although heavy investments in power plants were required.

Operating and Investment Costs in Making Aluminum Pig from Bauxite

Operation	Costs[a] Per Lb of Aluminum Produced	Investment Per Lb of Aluminum Per Year
Bauxite mining and beneficiation	0.5 to 1.1¢	2 to 6¢
Alumina manufacture	1.5 to 2.5	11 to 15
Reduction of Alumina	7 to 10	50 to 60[b]

[a] Operating costs exclude amortization or interest on the investment
[b] Includes capital cost of gas or coal fired power plant

ARTHUR F. JOHNSON is associated with the Metals Div. of Olin Industries Inc.

Bauxite Transportation

Handling bauxite by truck in the Caribbean countries is now restricted to hauling a mile or a few miles from the mines to the treatment plant. In British Guiana at the principal bauxite mines along the Demerara River a 36-in. gage railroad with 60-lb rail has been used from the mines to a washing plant. Since some mines are now about 40 miles distant, heavier rail is now being installed. At the mines on the Berbice River, bauxite is trucked a mile or less to a washing plant after which the washed bauxite is barged about 138 miles down river to the drying plant where ocean vessels with draft less than 18 ft can pick it up.

In Jamaica, Aluminum Ltd. makes alumina at the mine to eliminate all bauxite hauling, except a truck or scraper haul of a mile or even less. The alumina is hauled via a Government railroad about 35 miles to the coast where it can be loaded on ships. Reynolds uses an aerial tram to haul the dried bauxite 6 miles from the mines to the coast. Kaiser uses a 13-mile standard gage railroad, 70 ton gondolas, and 1200-hp diesel-electric locomotive to haul bauxite to a drying plant on the coast.

Towers being erected here now serve aerial tramway transporting bauxite from mine to Ocho Rios Bay, Jamaica.

Trucking Costs

Trucking is flexible transportation and competitive with narrow and standard gage railroads for short hauls particularly where care is taken to build good roadbeds which determine speeds as well as repair and maintenance costs. In the final transportation of aluminum from the fabricating plant to market, trucks are carrying an important part of the product because they speed delivery. Some fabricators have their own trucks and deliver to points 1000 miles or more away. An interesting new development is the loading of truck trailers, one or two per flat car, on the New York, New Haven & Hartford RR. This combination affords the flexibility of the truck with the lower cost of the railroad.

Since component items in trucking costs vary from place to place and from one year to another, data is given only as an example of cost computation. It brings out that repair and maintenance and fuel are radically reduced on a good roadbed where higher speed attained also reduces labor cost and illustrates that turn around time is important.

Regularly scheduled hauling by truck on U.S. paved highways can be done for 3¢ per ton mile and occasionally as low as 2¢ per ton mile, with a payload in both directions. Bauxite hauling costs in foreign countries must be corrected for the fact that truck parts will cost 10 to 25 pct or more, depending on freight and import duties. Skilled labor in the Caribbean may be as low as $14 per 40-hr week but lower productivity, more supervision, and subsidies to the mining camp community may reduce the advantage in labor cost to about one third or one half U.S. labor costs per ton mile.

Railroading Costs

Actual cost of most hauling by rail in the U.S. probably ranges from 3¢ per ton mile to 0.5¢ or less including capital charges as well as operating costs. Costs are less with regularly scheduled payload in both directions, or on long prairie hauls, and rise with less-than-carload lots, with payload in only one direction, or on short mountain hauls.

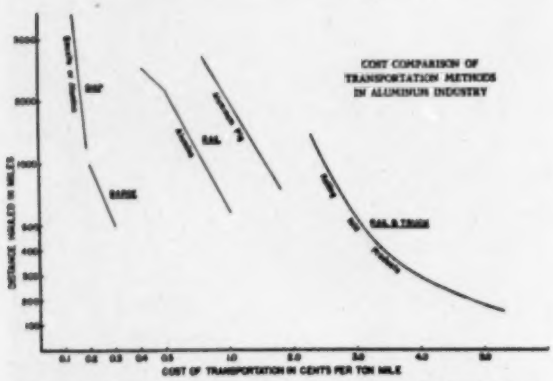
Using diesel locomotives, costs per train mile will be about 2.4 times the cost per locomotive mile. Average total costs per train mile can be converted to gross ton mile costs by dividing by the average 2900 gross tons hauled, and to costs per net ton mile by dividing by 1300 net tons hauled. From this, diesel haulage in the U.S. costs about 0.1¢ per ton mile, excluding enginemen's wages and handling of empties. For switching, the diesel is even more economical than steam.

Jamaica vs The Guianas

In Jamaica the bauxite has relatively little overburden compared to the Guianas. However, the topsoil which is stripped from the bauxite beds must later be replaced so the agricultural value of the land will not be impaired. For U.S. usage the bauxite is shoveled up, trucked or belt-conveyed to the drying kilns, pelletized and dried, hauled by aerial tram or railroad to the coast, and then shipped to alumina plants at Corpus Christi, Baton Rouge, and Hurricane Creek, Ark. For Canadian usage, the Jamaican bauxite is shoveled up and trucked a mile or so to an alumina plant where 2¼ to 3 LT of bauxite without prior drying yield a ton of alumina. Alumina is transported via rail to the coast and then by ship to Canada. Unfortunately, the U.S. has a $5.00 per ton import duty on alumina which offsets any freight advantage of alumina being made at the mines and shipped to the U.S. instead of bauxite on which there is only a 50¢ per LT import duty.

In the Guianas 1 to 5 cu yd of clay overburden along with a tropical forest cover must be stripped for each ton of crude bauxite mined. Crude bauxite may be trucked several miles or hauled by railroad up to 35 miles to a washing plant where about one third of the crude ore, consisting of clay with some fine particles of bauxite, is washed out and thrown away. The remaining clean, granular bauxite is dried and shipped to the U.S. or Canada where less than 2 LT of it are now required to make a ton of alumina. It contains almost all of the Al_2O_3 in the form of gibbsite ($Al_2O_3 \cdot 3H_2O$) which is more readily soluble in the caustic solutions of the alumina plant than boehmite ($Al_2O_3 \cdot H_2O$) commonly mixed with gibbsite in the Jamaican ores.

Cost Factors — Truck, Rail, Ship Transportation



In the U.S. a railroad track will cost $30,000 to $75,000 per mile, depending whether the rail is 90-lb used rail or 132-lb new rail with heavier ballast. The expense of roadbed preparation may double this cost.

Ocean Shipping Costs

Shipping costs vary radically according to the supply of ships. The past year costs have been dropping because there are more ships available and less demand for space. At present some charters are available for little, if any, more than ship operating costs; and bauxite can be hauled from Guiana or Surinam via Trinidad to the U.S. for about $6.00 to $7.00 per LT plus U.S. port charges of about $1.00.

Ton mile costs are increased by the turn around time. Hauling from Jamaica to Kitimat, about 10,000 miles round trip, it would require perhaps 23 days steaming time at sea plus 3 in port and 2 going through the Panama Canal making a total of 28. The unit costs per long ton mile must accordingly be increased from the above per day in service by roughly 20 pct. Alcan's shipping arm "Sagterms" of Montreal has chartered a standard Victory ship *S.S. Sun Karen* and altered her to carry 12,000 LT alumina at a service speed of 14 knots. Another new vessel *S.S. Sunrip* will carry 12,600 LT at 13.5 knots.

It is about 2500 miles round trip from Jamaica to New Orleans, 6000 miles round trip from the Guianas to New Orleans, and 6900 miles round trip from the Guianas to Arvida, P.Q. Shipment from the Guianas is complicated by the fact that ships with a draft of more than about 19 ft cannot get over the rivermouth bars into the Guiana ports. For instance, 4000 to 6000-ton vessels are used to shuttle from the Guianas to Trinidad where they are unloaded into land storage. Bauxite is reloaded into a 10,000-ton or larger vessel plying between Trinidad and the U.S. gulf ports or Arvida. The 10,000-ton vessel can take 45 to 50 pct of its load in the Guianas and complete the cargo by stopping off at Trinidad. On the return to the Guiana port the ship may carry 4000 tons of bunker C oil for drying bauxite there. In spite of the transfer charges involved, the haul can be contracted for about $6 to $7 per ton from Guiana to Gulf ports. The trend is towards

Estimate of Cost of Operating Ship Under U.S. Flag

Steamship payload capacity*		12,400 LT
Ship speed (16 knots)		18.4 mph 442 miles per day
Shaft hp		5000 hp
Fuel (0.62 lb bunker C per shaft hp-hr) (6.6 bbl per ton) (42 gal per bbl) (Cost in Caribbean approx. $2.20 per bbl)		$540 per day in service
Crew (U.S. Flag)		
Master	$1000 per mo	
3 Mates @ $466.67 Total	1400	
1 Radio Operator	500	
1 Bos'n	375	
9 Able Seamen @ $350	3150	
3 Ordinary Seamen @ $300	900	
1 Chief Engineer	950	
4 Engineers @ $525	2100	
3 Oilers @ $350	1050	
3 Firemen & Water Tenders @ $350	1050	
2 Wipers @ $300	600	
1 Steward @ $400	400	
3 Cooks @ $366.67	1100	
5 Messmen @ $275	1375	
Total	$15,950	
Add 60 pct for overtime, vacation pay, social security, etc.	9570	
Total	$25,520	
(Estimate 348 days in service per year and 17 days for annual repair)		$ 733
Subsistence for Crew @ $2 per day for 40 men		80
(Cont'd next column)		
Insurance 3.5 pct x value of hull plus average value of cargo ($4 million hull built in U.S. plus $1.3 million cost value of average cargo, @ $50 per ton for 12,400 tons alumina & @ 16¢ per lb for 6200 tons primary metal.) Cost per day in service		533
Administration $20,000 per yr for 348 days in service		58
Miscellaneous Ship Supplies, Rope, rags & Miscellaneous Consumable Supplies		80
Total per day in service		$2024
Total per mile of day in service		$4.58
Total per long ton mile of day in service with payload both ways		0.04¢
with payload one way		0.08¢

* Smaller vessels are usually powered with diesel fuel which costs $3.35 per bbl in Caribbean. It takes 0.33 to 0.43 lb per shaft hp-hr. Also crews are about 10 pct smaller.

Comparison of Rates of Crews Under Their Respective Flags

(Earnings in $ per mo)

	U.S.	Canada	Norway	Denmark	France	Britain
Master	$687.39	$475	$262.08	$254.64	$247.81	Variable
Radio Man	323.51	275	94.75	81.56	117.59	$102.77
Able Seaman	226.01	170	74.59	46.77	39.78	80.60
Fireman	214.18	170	76.00	71.55	41.30	84.63

(Since 1938 the basic rates of pay of U.S. crew members have increased more than 300 pct.)

Trucking Costs in Open Pits

(Computed from Data Published by R. W. Whitney in January 1952 "Mining Congress Journal")

	Poor Conditions $ per Hr	Good Conditions $ per Hr
Repair and Maintenance[a]	10.272	3.587
Labor (truck drivers)	2.323	1.757
Diesel Fuel	1.396	0.991
Total per hr	13.991	6.335
Cost per ton mile[b] operating cost	7.8¢ per ton mile	3.5¢ per ton mile
Amortization[c]	1.0¢ per ton mile	1.0¢ per ton mile
Total trucking costs	8.8¢ per ton mile	4.5¢ per ton mile

[a] Includes labor and all material and supplies

[b] Cost per ton mile estimated on the basis of 180 ton miles per hr as shown below:

1 mile haul with load (30 tons) @ 10 mph	6 min
1 mile return empty @ 30 mph	2
Total travel time	8
Time to receive and dump load	1½
Truck driver time out	½
Total time per cycle	10 min

Ton miles per hr in service
30 tons per truck x 6 trips per hr or 180 ton miles

[c] Amortization estimated for $30,000 truck and life of 3 million ton miles

Cost of Hauling Bauxite, Alumina, and Aluminum Pig

From	To	Approx. Miles Rail Distance	Lowest Rate Per Ton	Costs in ¢ Per Ton Mile
Bauxite				
Mobile, Ala.	Bauxite, Ark.	443	$4.025*	0.91
New Orleans	Bauxite, Ark.	448	4.025*	
Alumina				
Mobile, Ala.	Sandow, Texas	654	7.5785	1.16
Mobile, Ala.	Massena, N. Y.	1482	10.81	0.73
Mobile, Ala.	Wenatchee, Wash.	2779	10.557*	0.38
Mobile, Ala.	Vancouver, Wash.	2663	10.557*	0.40
Baton Rouge, La.	New Orleans, La.	80	1.311	1.64
Baton Rouge, La.	Spokane, Wash.	2399	10.557*	0.44
Corpus Christi, Tex.	Longview, Wash.	2633	10.557*	0.40
Corpus Christi, Tex.	Portland, Ore.	2584	10.557*	0.41
Hurricane Cr., Ark.	Listerhill, Ala.	315	5.06	1.61
Bauxite, Ark.	Alcoa, Tenn.	625	6.90	1.10
Aluminum Pig				
Vancouver, Wash.	Davenport, Iowa	2103	20.056	0.953
Sandow, Texas	Davenport, Iowa	1030	15.87	1.541

*Trainload 1800 tons Add 3 pct tax to all rates

Freight Rates of Aluminum Mill Articles

Midwest to the East by rail Effective Nov. 5, 1953

Distance	Cost in ¢ Per Ton Mile
50	11.6
100	7.39
200	4.83
300	3.95
400	3.42
500	3.10
600	3.00

Truck rates are approximately the same as rail rates up to 600 miles.

Operating Cost Comparison Steam & Diesel Locomotives

(Not including trainmen's wages)

	Steam	Diesel
Fuel	$0.5423	$0.2736
Water	0.0252	0.00155
Lubricants	0.0146	0.0286
Other Supplies	0.0066	0.0043
Engine House Expense	0.1154	0.0290
Repairs	0.4846	0.2180
Total per Locomotive Mile	$1.1887	$0.55505

NOTE: Costs above are for 125-ton locomotive, average U.S. engine and tender weigh 308 tons. A 180-ton diesel will haul 2040 tons up 0.2 pct grade at 30 mph, 2020 tons up 1.4 pct grade at 9.9 mph. AMORTIZATION: Cost of 180-ton diesel is $206,200, average life 25 years, and 400 million payload ton miles.

Freight Cars

Weight: Average (empty) 20 tons per car, loaded box cars 60 to 75 tons

Cost: 50-ton box car $6000
50-ton hopper 5000

Maintenance: box car $364 per year
hopper 334 per year

In 1952 serviceable freight cars on U.S. class 1 railroads averaged 355,000 net ton miles.

Capital Cost of Railroad Bed

	$ per Mile of Track
3000 ties @ $4 each	12,000
Slag, 50 cars @ $200	10,000
Rail, used 200 tons @ $80	16,000
Other track material	5,000
Labor @ $2 per track ft	10,568
Total	53,568

Bauxite Analyses

Location	Al_2O_3	SiO_2	TiO_2	Fe_2O_3	H_2O
Jamaica	50.65	1.09	2.52	19.53	26.2
African Gold Coast	49	1		22	
Surinam	57.8	2.9 est.	2.4 est.	5.2	
British Guiana	Est. approx. same as Surinam				

Skilled labor in the Caribbean may be low in dollar per hr cost, but lower productivity, more supervision, and subsidies to community reduce advantage in labor cost.

larger and towards quick unloading vessels to save turn around time and stevedore charges in port. Reynolds' ship named after the late Carl Schmedeman, AIME member, is a 13,000-ton capacity ship plying between Jamaica and Corpus Christi and is reported to be making the 2000-mile round trip in about 9 days with loading and unloading time of only 8 hr each. The quick unloading is done by a self-contained belt unloading system on the ship. Alcoa is reported building a 32,000 and a 26,000-ton vessel as well as an 8,000-ton ship for shuttle service. The crew of the 26,000-ton ship is estimated as 51, speed 12.75 knots with 5800 hp, and cost $5 million built in Norway.

Such ships can be built cheaper abroad although U.S. machinery is generally preferred. Cost of a hull plus machinery in Japan is perhaps $150 per deadweight ton compared to $300 in the U.S. Wage costs are about three times as much with U.S. crew under the U.S. flag as with British, Dutch, or Norwegian crews under their respective flags. A comparison of monthly rates of pay in 1950 taken from *Forbes* magazine is shown in the tables.

Barging Costs

Barging has had an interesting history in its application to freight movement of bauxite. It forms a cheap means of freight movement in South America and Africa where railroads inland have not been built and still offers competition to U.S. railroads in the Mississippi River Valley and coastal areas. For Mississippi River barge traffic a 9-ft deep channel is necessary to compete with other forms of transportation, and 14 to 16 barges with 1300-ton capacity each may be moved by one tug. Barging can be contracted for a cost of about 0.25¢ per ton mile of river distance. In the shallow and narrow upper portions of the South American rivers two or three 400-ton capacity barges have been towed by one tug.

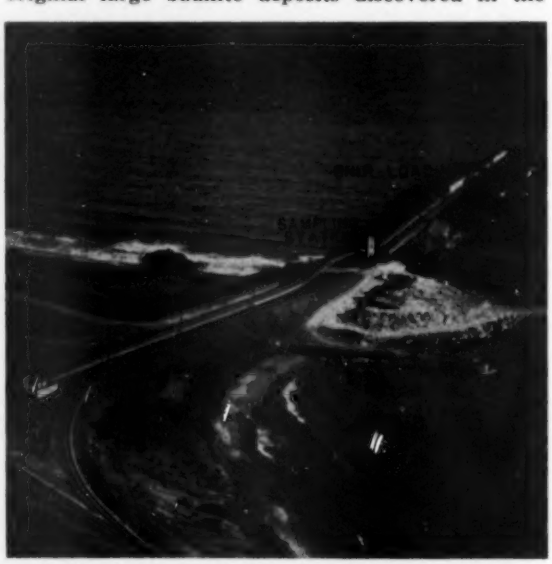
From the foregoing analyses of transportation costs for foreign bauxite it is easy to compute that the freight on a ton of foreign bauxite to its alumina plant is much greater than the value of the bauxite at the mine, unless the alumina plant happens to be located at the mine. This is the case of Aluminum Ltd.'s plant in Jamaica and becomes economic because no import duty on alumina to Canada is involved and process fuel would cost as much in Canada as in Jamaica. The characteristics of the ore both physically and chemically also make location of the alumina plant in Jamaica advantageous.

Size of Deposit and Mining Cost

In considering whether a bauxite deposit is economic, capital expense must be amortized by the recoverable tons. In Guiana or elsewhere high stripping ratios on small bauxite beds, which are irregular in size and do not justify large stripping equipment, may make a deposit uneconomic, particularly since wet screening to wash out the clay may lose 20 pct or more of the bauxite in the form of fine particles. There is apparently a great deal of room for improvement in the beneficiation of bauxite either by reducing losses of fine particles, or substitution of a new unit process.

Bauxite shipped from either Jamaica or the Guianas is usually kiln dried to bring the free moisture down from an average of perhaps 18 pct to 2 pct and so save 15 pct on freight. Due to the fine particle size of the dried Jamaican ore it is dusty and constitutes a handling problem unless special equipment adapted to its characteristics is provided.

Some bauxite deposits although good quality may be so small that building roads imposes too great a capital expenditure. Road construction in the Guianas is expensive on account of the need for chopping down the forest covering and is also expensive in Jamaica when rugged country is traversed. The original large bauxite deposits discovered in the



Sampling station and ship loading point here serve Kaiser's Jamaica bauxite operation. Port and railroad to mines inland represented part of capital cost of opening up this deposit.

Ore Characteristics Influencing Process Cost

In the treatment of bauxite by the American Bayer process to produce alumina, approximately a pound of alumina and sodium carbonate are lost for each pound of silica present in the ore. In evaluating the two ores on this basis, one might be inclined to estimate that the Jamaican ore was almost equivalent to the Guiana ore. However, other factors must be considered. The first of these is the relative gibbsite and boehmite content. Gibbsite is the trihydrate of alumina and is easily soluble in American Bayer process caustic solutions. Boehmite is the monohydrate of alumina ($Al_2O_3 \cdot H_2O$) and requires European Bayer process solutions at higher temperatures with stronger caustic to readily effect solution. Some Jamaican ores contain up to 25 pct of their alumina in the form of boehmite while British Guiana or Surinam bauxites probably have less than 3 pct of the alumina as boehmite.

Another factor affecting the amenability of the ores to low cost treatment by the Bayer process is the relative amount of red mud tailing produced for each ton of alumina recovered. The iron, titanium, and other minor minerals present are insoluble in the Bayer caustic solutions but their total surface as determined by their combined weights and mineral particle sizes in the red mud affects their settling and filtering rates and affects the amount of alumina and soda held in the red mud and so lost as tailing in the process. In this respect the British Guiana and Surinam ores are also better than the Jamaican ores since the latter not only have relatively more red mud per ton of alumina but have it in probably the finest mineral particle size that occurs in nature. The early alumina plants built to treat the British Guiana and Surinam ores filtered all the red mud from the caustic solution after digestion but alumina plants built for domestic ore (which contains clay minerals that make voluminous red mud) as well as plants built to use Jamaican ores settle and wash the mud in thickeners instead of filtering it before discarding it. The unit process of settling and washing in Dorr thickeners is essentially cheaper than the unit process of filtration in labor, filter cloth, and capital charges but has some disadvantages in the Bayer process in that it loses more heat from the boiling hot solutions, does not recover soda and alumina as completely as filtration does and by requiring more wash water increases the amount of evaporation necessary in the Bayer process. It is doubtful if a new alumina plant to treat boehmite type bauxites can extract alumina as cheaply as a new plant built to treat gibbsite type of bauxites although a new plant may be more efficient than an old one even with less amenable ore. In considering the economic value of a bauxite ore, the problem never resolves itself into such a simple question. Some Jamaican bauxites contain very much less boehmite than others. Haitian bauxite reserves contain more boehmite than Jamaican ores.

Guianas and Jamaica contained tens of millions of tons of recoverable ore and therefore could amortize large treatment plants, railroads, and ships. Many remaining scattered deposits containing only a few hundred thousand tons can become economic if mobile beneficiation plants or cheap truck transport to a central plant over good roads are eventually used.

The average bauxite bed mined in Jamaica or the Guianas is about 25 to 35 ft thick, although occasionally deposits do occur up to 100 ft in thickness. In the past overburden has been removed chiefly by power shovels or by self-loading tractor-drawn scrapers but now as high overburden ratios are encountered in the Guianas, walking draglines as well as hydraulic methods are finding an increasing use. Present stripping ratios in British Guiana are about 3 to 1. Surinam average is lower.

The rate of mining largely determines the size of equipment that can be profitably employed for stripping. For instance, in a bauxite deposit with an overburden ratio of 5 to 1, it might pay to employ large draglines for stripping. Under suitable conditions, where adequate space can be found for overburden disposal, costs as low as 4 to 8¢ per cu yd are possible. Hydraulic methods are well suited for removing soil or sand overburden where topographic conditions permit and, under favorable circumstances, stripping by this method may be cheaper than by dragline because of much lower capital investment. In hydraulicing the greatest element of cost is for power to run the pumps that supply the water and carry away the overburden. Pumps are sometimes, but not always, needed to carry the overburden slurry to a suitable disposal point. Pumping as a means of transportation has been suggested for coal and it might be used for bauxite at a low cost per ton mile, although there are many factors to be considered, such as attrition of the bauxite and subsequent loss of bauxite values on dewatering.

For bauxite deposits which are small in size or where overburden is shallow, stripping is often done only with tractor-drawn scrapers or by power shovels loading into the trucks. The cost per yard stripped by these methods may range from 12 to 20¢ even with the advantage of low cost labor. Sometimes several of the above-mentioned stripping methods may be employed simultaneously at deposits where overburden ratios and topographic conditions are variable.

Walking draglines are used in both Surinam and British Guiana. In the latter country Alcan operates one such machine with 200-ft boom and 8-cu yd bucket. A second one is now being delivered that will have the same bucket capacity but longer boom of aluminum construction. Increasing overburden ratios create a disposal problem and in such cases it is desirable that stripping draglines have long booms so that as much overburden as possible can be stacked in the available disposal area.

From the long range viewpoint foreign bauxite cost will rise gradually with increasing wage rates and taxes excepting where producers are able to counteract such increases by improved handling methods. Domestic bauxitic clays and anorthosites may ultimately replace foreign bauxites as a source of aluminum. Although treatment costs are greater on domestic ores, transportation costs between plants are greatly reduced.

Exclusive of the cost of bauxite, operating costs of making alumina may run from $15 to $25 per ton of alumina produced. This operation cost is made up chiefly of labor, repair, and maintenance, 12 to 14 million Btu of fuel and the caustic soda lost in the red mud. The cost of the 2 or 3 tons of bauxite needed may exceed the total treatment costs when stripping, mining, beneficiation, and transportation to the alumina plant are all considered. Capital charges for the alumina plant, the mining plant and ships to carry the bauxite add to the total cost of production.

Four major reasons for controlling classifier overflow density—

- ► To control particle sizing
- ► To control flotation circuit feed
- ► To maintain maximum load in ball mill
- ► To minimize sliming

led to Bunker Hill's . . . . .

Density Recorder and Controller

by Alvin F. Kroll

BUNKER Hill & Sullivan Mining & Concentrating Co. has three major sources of ore at present: high grade square-set ore, low grade caving ore, and low grade reclaimed washed jig tailing. These three ores constitute the feed to the 3000-tpd concentrator that produces lead-silver, zinc, and pyrite concentrates. Each ore has different characteristics of grindability, mineral particle size, composition, and content, but all are amenable to the same mill circuit and reagents. The gangue is primarily quartzite.

The Bunker Hill concentrator is now using a coarse primary grind followed by a regrind of sand fractions of lead rougher tailing, lead middling, and lead cleaner tailing, and further regrind of sand fractions of zinc middling and zinc cleaner tailing. This is done in order to recover all valuable minerals at the largest size possible. The tendency to overgrind the ore particles, which are more easily ground than the gangue particles, is thereby reduced—lessening their loss in the flotation tailings. The coarse primary grind and regrind method has the advantages of: providing more selective grinding, minimizing sliming, giving a cleaner lead-zinc separation, and reducing mill requirements for reagents and water. Improved lead-zinc separation raises overall recovery and also increases lead and zinc recovery in the respective concentrates by keeping middling particles out of concentrate and tailing.

Grinding Circuit

The grinding circuit consists of fine ore bins, belt feeders controlled by Hardinge Electric Ears, and 10½x8-ft Union Iron Works ball mills operating in closed circuit with Akins 48-in. duplex double-pitch submerged spiral classifiers. Feed to this circuit is a composite of the three major ores, sized —⅝ in. Since no actual attempt is made to blend the three ores, grindability of the ball mill feed can change quite rapidly and the classifier overflow density can change several points before the operator is aware of it. Due to this, the spread of particle sizes in the classifier overflow was greater than desired for uniformity in the flotation circuit.

This fluctuation is illustrated by Chart No. 1. Although actually a measure of percent solids or density, the chart directly reflects the spread of particle size as density varies. Screen analysis of classifier overflow illustrates the variations of particle size at three different densities.

Variations that change the grinding conditions and result in overflow density changes (actually changing the classifier overflow particle sizing) are: 1) changes in ore, 2) size of feed, 3) moisture content of ore, 4) circulating classifier load, 5) Electric Ear setting, 6) mill feed slime thickener discharge, 7) bin segregation. Although the Hardinge Electric Ear maintains a constant load in the ball mill at a particular setting, it is not possible for the operator to control and anticipate variables that affect the classifier overflow and change the particle sizing. In order to control the classifier overflow percent solids and actually control particle sizing, experimental and research work resulted in perfection of the Bunker Hill-Bailey Meter density controller and recorder.

A year of operation has proven it a satisfactory density controlling and recording installation. Chart No. 1 illustrates percent solids of the classifier overflow, the circuit dilution water being manually controlled with the chart not visible to the operator. *Chart No. 2 illustrates how automatically controlled classifier circuit dilution smoothed out the operation.*

Density Controller and Recorder

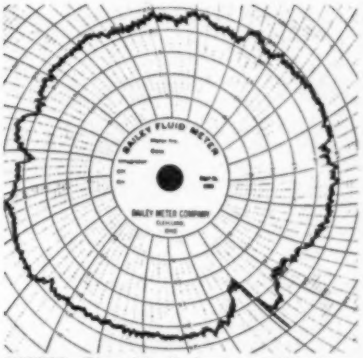
The drawing shows the circuit for the classifier density control that uses clean, dry compressed air at 30 psi for operation. A constant amount of air is passed into each of two bubble tubes, the open ends of which are submerged in the pulp. If one bubble tube is immersed farther than the other, a greater pressure will be required to bubble the same amount of air through the deeper one. The difference between these two pressures then serves as an index of density. A constant differential relay provides a constant air supply for the bubble tube and a rotameter indicates the amount of air being supplied.

The two pressures from the bubble tubes are applied to the sides of a diaphragm mechanism in the Bailey indicator-controller and cause the instrument to operate. The indicator-controller sends out an air loading pressure, proportional to the density. This pressure is used in the control system and transmits the density indication to the recorder. The air loading pressure, modified by the Standatrol

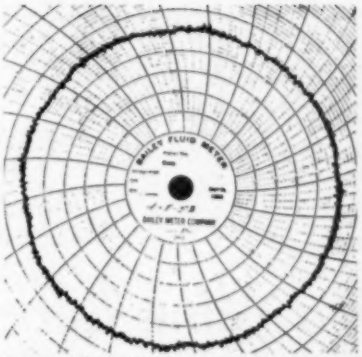
Screen Analyses for Three Overflow Densities

Mesh	At 40 Pct Solids Pct Wt.	Cum. Pct	At 50 Pct Solids Pct Wt	Cum. Pct	At 57 Pct Solids Pct Wt.	Cum. Pct
+ 35					6.71	6.71
48			3.16	3.16	9.55	16.26
65	1.74	1.74	5.43	8.59	9.03	25.29
100	9.37	11.11	10.54	19.13	11.49	36.78
150	11.48	22.59	10.12	29.25	8.78	45.56
200	10.47	33.06	8.63	37.88	7.10	52.66
325	14.88	47.94	12.59	50.47	10.09	62.75
—325	52.06	100.00	49.53	100.00	37.25	100.00
	100.00		100.00		100.00	

ALVIN F. KROLL is Assistant Concentrator Superintendent, Bunker Hill & Sullivan Mining & Concentrating Co., Kellogg, Idaho.



BEFORE: Chart No. 1 shows variation in per cent solids with manual control of circuit dilution.



AFTER: Chart No. 2 shows how operation smoothed out under full automatic control of dilution water.

KEY TO CONTROL is sampling funnel shown with bubble tubes, foreground. Water control valve is above.

relay, which corrects for offset resulting from changes in load, passes through the selector valve when it is in the automatic position and is applied to the air-operated water control valve. As the water control valve opens or closes, it increases or decreases the dilution of the slurry in the classifier. The range of the indicator is approximately 1.05 to 1.95 sp gr or a range of 10 to 75 pct solids by weight assuming an ore of 3.0 sp gr.

A second Bailey controller has recently been installed and a second pen added to the recorder. A different chart is being used now with one pen offset 10 pct so that the recorded lines do not overlap.

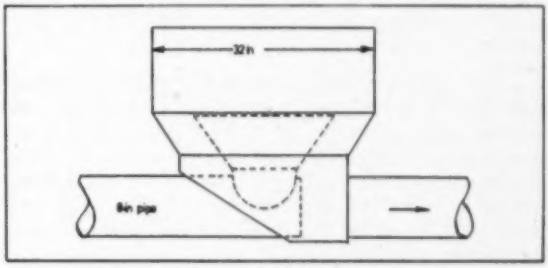
The sampling funnel provides a point at which the entire classifier overflow will pass and at which its density can be measured. Velocity of the slurry through the funnel and the shape of the funnel are such that slurry remains fairly uniform, but at the same time the funnel reduces the turbulence of the slurry to such a point that its density can be measured readily. Success of the installation is primarily due to the sampling funnel, for it was determined that all previous installations of the bubble tubes in the classifier overflow line and in the classifier pool did not represent a true condition.

Bubble Tube Location

Installation of bubble tubes in the classifier overflow line proved unsatisfactory due to turbulence and frothing. Bubble tube placement in the classifier pool also failed to provide the solution to the problem because of the variation in density in both the vertical and horizontal plane. Variation in density was also discovered at different points along the classifier overflow lip. In an effort to find a point in the classifier pool that gave consistent results, the bubble tubes were shifted to various points within the classifier pool, and as much as 40 in. from the lip. Changes were made in depth and depth differential of the tubes, tubes were installed on a float, and a weir was installed on the classifier lip to converge and mix the pulp before it overflowed.

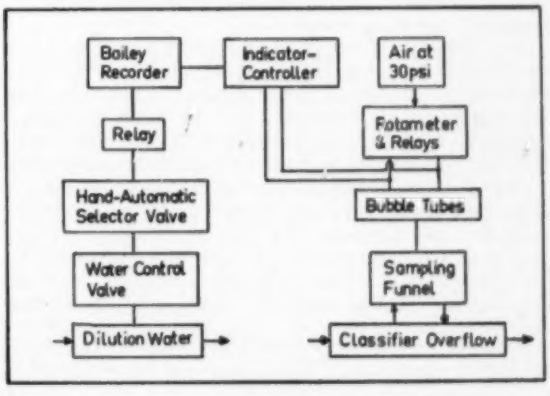
None of these changes gave the desired results because the variation in pulp density with depth is itself a variable over a period of hours or days. Thus the bubble tubes actually measured the average density from ½ to 3 in. below the surface at their particular location and while the controller might keep this region at the desired density, the actual overflow density might change. Numerous other changes were made in the installation but the solution proved to be the present position of the bubble tubes in a double-walled cone in the classifier overflow line.

Control equipment developed by Bailey Meter Co. for this job is comparatively simple, trouble-free, and operates exceptionally well. The secret of any installation, such as this, is to be sure that the point of measurement represents the true condition. In this case the secret or point of measurement is in the



sampling funnel. To date, advantages or disadvantages derived from automatic control have not been evaluated and proven, but indications are that the more uniform operation and more uniform particle sizing have improved the flotation control giving lower tailing and high grade concentrates. This uniform particle sizing has leveled out the load in the return to the regrind circuit which again is a factor in smoothing out the flotation operation. Although no definite proof is available, indications are that the original tonnage fed to ball mills has increased.

The author wishes to thank Mr. J. B. Haffner, general manager; Mr. C. Y. Garber, superintendent of concentration; Bailey Meter, engineers Mr. K. Atwood and Mr. F. Mehle; and Mr. Jay Silva and members of the Bunker Hill Smelter Instrument Dept. Thanks are also due to the concentrator operating personnel.



Mining as an industry is unique—but its problems are not. Drawing a parallel to other industries the author finds five steps in a pattern for . . .

Reducing Mine Labor Cost

By T. M. Barry

HOW often have those who make mining a career said that, "mining is different"? This kind of feeling often expresses itself in talking shop with men of other industries. And there is no doubt about it; mining *is* different. There are different marketing problems, different production problems, and we certainly have different personnel problems, to cite but a few.

Mining people have recently been discovering though, that many of their problems are *not* unique to mining. They are beginning, in fact, to find that many of them are dead ringers for problems that other industries have had to face and solve years ahead of mining.

An especially good example of this is the whole field of labor cost control.

There are two factors that set mining's labor cost history apart from the bulk of other businesses. One is the peculiar history of its productivity. For many years miners were paid direct incentives. Their personal efforts were high, for they were paid in direct proportion to the amount of work they performed. These were primitive incentive plans when compared to the type available to today's managements; yet as unfair as they were to the workers, they managed to get results. Most of the miners have been shifted to daywork pay in recent years, and the personal efforts of the miners have fallen to typically daywork levels.

The other factor that has influenced mining's labor cost history has been an accented profit cycle. Profit, in any business, is the difference between cost and sales (or realization). In the high overhead business of mining, when realization drops, production falls off with it and unit costs climb. Similarly, when realization climbs, productive capacity can be best used and unit costs drop. Basic increases in wages have accompanied many of these "good profit" sides of the cycles, but have not been adjusted downward in times of profit squeezes. And an important factor is that these wage costs have increased out of proportion with the rest of American industry.

Well, there it is. A recognition that basic labor costs have climbed out of keeping with the normal rolling growth of our economy and that there has been a definite reduction in the miner's effort.

What is the cure? How can the industry get best value from its labor dollars? Let's take a look at some fundamentals:

The work of *any* man, working for *any* company in *any* kind of business, will be done faster, and thus more cheaply *if:*

1. **He is given better equipment, or**
2. **He uses better methods, or**
3. **He exerts more skilled effort, or**
4. **He is exposed to fewer "external" restrictions (delays he himself cannot avoid).**

Concentrating on those last three points gets to the grass roots of labor cost control. Equipment is always a problem; better equipment seems to be always available. A company that has tight labor control is one that, while recognizing that there is always better equipment available, does get high utilization from today's equipment, today.

And there is the definition. *Good labor cost control gives us a situation where all of our people are working at their jobs at the best methods we know, at a good conscientious rate of effort, and with little or no delays.*

Let's see how these conditions are met.

The author thinks the answer is a combination of:

1. **Soundly planned organization structure,**
2. **Competently manned organization,**
3. **Performance and cost standards and methods based on *engineered* (time-studied, etc.) research,**
4. **An enlightened approach to the dignity of the working individual, and,**
5. **Incentive rewards for incentive performances.**

T. M. BARRY is a partner of Barry & Co., management engineers, Los Angeles.

This is the pattern . . .

THE ORGANIZATION STRUCTURE does not seem to track to any firm pattern. Many are tried and many are successful. The committee management pattern, line and staff pattern, purely functional pattern, and others are working well every day. One quality seems to be important, though, and applies to all such plans: that they be firm and clearly understood.

THE KEY MEN and WORKERS can retard overall productivity if they are not qualified for their jobs or are not trained for them. Organized recruitment and training of qualified key people has been shown repeatedly to be a field of great reward. The same is certainly true of the workers. Getting a good man in *every* position of a company is a real challenge—but can be done with long-range recruitment and training programs.

TIMESTUDY and all of the other industrial engineering tricks are the only sane tools for finding how long a job should take normal, conscientious workers to perform. This opens up the whole stage for cost control. Timestudy tells how long each job takes, and permits examination of each move to see what can be done to improve the job. When it is done in conjunction with other workers, it gives *facts* with which to balance work assignments among the various members of a crew. It shows what the delays were and how critical they were, and makes it possible to learn the extent of any harm from avoidable delays. With these once isolated, management finds itself in a position where it can put in some simple, workable systems for reducing these delays.

This overall picture seems to be so very important. Does an architect ever complain about working with people? They all want certain effects in their house which, combined, might clash, either costwise or esthetically. The architect can give them precisely what they want if they will just state their real problems. In the same way that a kitchen cannot be laid out without regard to where the other rooms shall be put, the findings of timestudy and other engineering research avoid the development of a delay control which is fine in its results for one department but upsets the performance of another. They help get the whole picture.

HUMAN RELATIONS is a fairly new name for an old American principle. There has been a lot of recent research to pin down the relative importance of varying degrees of worker contentment in terms of the resulting long-range effect on worker productivity. Strong positions have been taken by a lot of men who run industries. Many feel that great sums can be spent in nurturing a happy company and still have the higher productivity offset this cost. Others feel that all *fringe* benefits and company spending to develop intraplant harmony are wasted dollars. Still others feel there is an in-between. It can be surmised that any general trend is worth noticing, and recognized that there is a trend toward voluntary company spending, far in excess of organized labor requests, to improve worker satisfaction. The trend seen most often in industry is toward making each individual feel as if he is a very important part of the company. The methods are many, and the results vary, but are generally most favorable.

INCENTIVES are getting a little kicking around these days. In perhaps their most successful form they *guarantee a worker an earning base, then reward him in direct proportion to work performed above the normal task level.* Mining had some bad experiences with incentives because these simple requirements were not fulfilled. Under most contracts the tasks could not have possibly been considered normal. An industry wide or area-wide contract cannot specify what the normal requirements would be for each man of each section of each mine of each seam in an area. And, of course, there was seldom a guarantee of an earning base.

Industry has had more luck with incentives. It has been able to install them with standards that do apply in their own cases. Results of most such incentives are very good. *It is not uncommon for a new incentive scheme to lower unit labor cost 35 pct.* Some companies are discarding their "old" incentives, because they "don't work anymore". These old incentives, if examined, will invariably show that the standards were no longer *fair* or that the bonus leverage was too low. No incentive plan will work if it is not kept practical, kept fair, and kept accurate. There is no labor control known to the author that will have such enthusiastic endorsement from management as a carefully installed, intelligently run extra pay plan.

These are not new facts to many operators. Many have recognized weaknesses in methods, worker effort or delay control, and have tried to correct the conditions by *drives* on work simplifications and methods, etc. This approach is not unsuccessful; it gives only temporary relief, however.

Better methods, better worker effort, better worker skill, and better control of downtime do not come casually. There is a great deal of cost at stake in these areas, and it is worth going after, but the way to get top cost reductions and *hold* them seems to require more than an occasional drive.

Those five points, detailed above, are your master pattern for cost relief. Its best selling point is its steady increase in popularity among nonmining industries. It will work for mining companies just as well as for any industry. Some have already been very aggressive in making the swing, and it is our feeling that mining, as an industry, can show greater savings by rigidly adopting this sort of a management pattern than any other major industry.

Two headframes and ventilation fan at Southwest Potash Co.

Potash Mining Methods

by Henry H. Bruhn

and Earl H. Miller

COMMERCIAL beds of sylvite ore were discovered by the Snowden & McSweeney Co. while drilling a wildcat oil well some 25 miles northeast of Carlsbad, N. M., in 1925.

After a preliminary core drilling program the U. S. Potash Co. sank a 1060-ft shaft within 4 miles of the original discovery. This shaft was in an isolated location in a sand desert area with only the roughest of dirt roads connecting it with the neighboring town of Carlsbad some 21½ miles west.

Since little was known in this country of potash mining practice, original development was based on metal mining practice. The first shaft was a four-compartment timbered shaft, the hoisting compartments being 66 in. by 46 in. between the guides.

First mining was done in drifts 8 ft wide and to a height varying with bed thickness, using a bottom V-cut round drilled with air-driven rock drills. In a short time drifts were widened to 16 ft and later to 20 ft when locomotive haulage was installed. Within a year and a half coal undercutters and electrically driven auger drills were tried out so successfully that they became standard equipment. A room-and-pillar mining pattern then established with rooms and breakthroughs 36 ft wide is still used with minor modifications. Blasting practice in room-and-pillar mining is still a matter of constant experiment and research, as potash ore is quite plastic and *springy* with heavy charges of high strength powder necessary for proper fragmentation.

Box type scrapers operated with 3-drum Sullivan hoists installed on track-mounted loading slides were used for placing broken ore into 24-in. gage rail cars. This method of loading was quite economical due to low equipment maintenance cost, even though installation of trackage and switching was expensive. In places ore less than 7 ft high was encountered and these low rooms were not easily worked because of lack of head room for the scraper loading machines. In 1942 Joy loading machines and rubber tired shuttle cars from the coal industry were tried out and quickly replaced scraper loaders.

Within a year after the No. 1 shaft was sunk at the U. S. Potash Co. operation, a second shaft was put down 2250 ft south of the original one in order to take care of ventilation and also to permit the use of larger crews of men underground.

The first ore mined by the U. S. Potash Co. was shipped January 1931, the product being trucked over a rough dirt road to Carlsbad, where it was transferred to the Santa Fe Railway. By September 1932 a hot solution refining plant had been constructed, and a high grade refined potassium chloride was shipped to market by rail.

U. S. Potash Co. is now mining on one level and developing an upper level. A room-and-pillar method of extraction is used, with both rooms and breakthroughs still 36 ft wide, with pillars in the panel areas 36x82 ft, or 58x58 ft, depending upon the nature of the back. On main triple entry haulageways barrier pillars 150 ft wide are left on either side with breakthroughs in these pillars at intervals of from 200 to 400 ft, depending upon entry needs. Bed thickness varies from 6 to 13 ft with extraction within a panel at 60 pct or a little better, and overall extraction in the mine is very close to 50 pct.

Faces are undercut with shortwall coal mining machines which in some cases, have been redesigned for use in the more rigorous potash mining service. A 9-ft cutter bar with both tungsten carbide undercutter bits and a double-ended alloy steel bit is used to cut an 8½-ft depth. The center of the undercut kerf is carried on the line between ore and underlying rock salt, although sometimes this is difficult.

Drilling and Blasting

Blast hole drilling is done with post-mounted auger type coal drills and Joy CD-34 drills which were first developed for potash use at the U. S. Potash Co. property. The Joy CD-34 is a two-drill hydraulically operated machine with a capacity of 10 fpm per drill. Double-tipped tungsten carbide auger type drill bits are used. A later development using hollow drill steel with an auger type bit and compressed air to remove drill cuttings has also proven quite successful. Alloy steel detachable cutters and tungsten carbide tips are used on the post-mounted auger type drills. One and one half in. bottom diam holes for a 1x8 in., 40 pct ammonia

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dynamite are present practice. An average 9x36-ft face is drilled with 50 holes. The drill pattern calls for five rows of ten holes, the top row of holes is drilled horizontally or slightly upward, and each succeeding row points downward at a steeper angle with the lower row of holes bottoming within 9 in. of the back of the undercut. It has been found that accurate drilling must be done if the proper break on the ore is to be achieved. Face bosses measure and mark the hole locations on each face, and predetermined angle settings on drill equipment are used in order to have the proper positioning of each hole. All blasting is done with millisecond delays and battery equipped condenser type blasting machines with the bottom row of holes being fired first and the balance of the firing progressing out and up.

After blasting, ore is loaded with Joy 11 BU loading machines into Joy 60E shuttle cars which move the ore to an elevating conveyor which loads the 4-ton Granby type ore cars at the rail head. A few Joy 14 BU loaders are used in thin seam mining with Joy 32E and 42D shuttle cars but the major work is done with high equipment.

Haulage

Ore is hauled to pockets at the No. 1 shaft on 24-in. gage track by various types of electric trolley locomotives. These units vary in weight from 6 to 20 tons each and are all of the 4-wheel type. The latest 15-ton GE electric locomotives purchased are designed to be run either separately or in tandem and have a 7500-lb drawbar pull at 10.5 mph. Controls on these locomotives are so designed that up to four or more of them can be coupled in tandem and operated from one control point, permitting adjustment of motive power to any grade or tonnage.

There are about 200 miles of open workings at the U. S. Potash Co. Studies have been carried on over the years, showing an average convergence in the older workings of about ½ in. per year. On a few occasions floor bursts have occurred, presumably caused by trapped pockets of high pressure nitrogen gas combined with pillar pressure on either side of the break. At some locations in the mine, floors have shown a tendency to bulge upward in the center, probably due to pillar pressure on softer underlying strata. Back conditions are good throughout a large percentage of the mined area, but in one section of the operation a mud seam, which varies from the ore-salt contact to as much as 4 ft into the overlying massive salt, is a line of weakness which after a period of time allows falls of back salt to occur. In order to control this roof a small amount of timber and roof bolting is used. Roof control is not necessary for immediate mining safety, but future plans call for removal of most of the remaining pillars and heavy falls of salt in the mined area must be prevented, as they can interfere with later recovery operations.

Development of new orebodies to the north of the present workings calls for up to 8 miles of underground main line haulage. In order to handle ore movement, 42-in. gage track is being installed in one side of a double-entry haulageway, and a 40-ton scrubber-equipped diesel electric locomotive built by the General Electric Co. to specifications set up by U. S. Potash has just been put into service. This locomotive, 6 ft in overall height, 7 ft wide, and 47 ft 7 in. long, will handle trains of 10-ton Sanford-Day bottom dump cars at speeds up to 30 mph.

Continuous Mining

Three Joy continuous miners have recently been put into service at U. S. Potash properties. These machines are the standard Joy coal mining machines and on first trial have shown many weaknesses for the much heavier duty required in mining potash ore. Weak points are being redesigned and indications are that continuous mining may become a standard practice in sylvite mining. One of the problems encountered in continuous mining is the control of dust developed by the cutting head. Sprays of water cannot be used on this highly soluble ore, and methods of air control with dust collection behind the working area are being tried.

In the development of its north orebodies the company is sinking a third shaft to be completed early in 1954, to be used for ventilation and servicing of the northern end of the mine. This shaft is circular in section, 15-ft ID with concrete lining through 600 ft of overburden to the salt measures. It is unlined through the salt, and will be 1350 ft deep with a concrete dividing wall carried from top to bottom. Use of this shaft as a service entrance will permit the lowering of large pieces of mining equipment without the need for the complete dismantling and cutting into small parts now required.

Large volumes of water occur in the sedimentary overburden and before shaft sinking started, a circle of bore holes was carried down into the top of the

This new 40-ton diesel electric locomotive was built for underground service at U. S. Potash operations by General Electric Co.

Joy Continuous Miner in a 9-ft potash bed. Appearance of back and walls is typical of machine cutting. U. S. Potash Co.

salt and pregrouting under high pressure was done. On sinking it was found this pregrouting was quite successful except for one thin water-bearing sand strata at 520 ft, which caused delay in sinking, and a need for further grouting from a point just above the water zone. This zone was successfully sealed off and shaft sinking under dry conditions followed.

In the development of the north orebodies a high speed, self-dumping shuttle haulage device was needed quickly. The problem was solved by shop conversion of diesel equipped, GMC highway tractors to low head units equipped with 15-ton self-unloading trailers. The trailers were equipped with 21.00x25, 24-ply logging unit tires and wheels, and an exhaust scrubber was fitted to the tractor unit. Three of these units have been in service for nearly 2 years and have proved to be quite effective in hauling waste salt from entry faces and placing the salt for backfilling in worked-out mine areas. The back-fill salt has been stacked to the roof with D4 Caterpillar diesel bulldozers equipped with scrubber units built by the Ruth Co., Denver.

Underground power distribution has been by 2300-v ac circuits with skid mounted transformers in panel areas reducing voltage to 220 v ac. Power for haulage systems has been converted with motor-generator sets or mercury arc rectifiers to 250 v dc. Due to the large area now mined, voltage drop difficulties were encountered with 2300 v distribution and a new 12,470 v system has been installed in certain areas. Power is transformed from 12,470 v to 2300 v at outlying points and distributed up to a mile at 2300 v. The old standard transformer equipment to drop from 2300 to either 440 or 220 v in panel areas fits this new program.

Hoisting is being done with Nordberg, Stearns-Rogers, and Wellman-Seaver-Morgan hoists of various sizes and rope pulls. Ore skips of 4.8 tons capacity operate in balance at speeds up to 1500 fpm.

Ventilation

Ventilation at this mine is done by Jeffrey reversible Axivane fans. Normally all mine air is moved by a fan located underground near the foot of No. 2 shaft, but in case of an emergency, a fan located at the surface of No. 2 shaft can be put in service by dropping temporary trap doors over the top of the shaft and using this surface fan as a suction fan. A third fan was installed in the return airway of the two north entries to serve as a booster in ventilating the extreme end of the north development. Now, 158,000 cfm is being moved through the mine workings with the air flow directed by American Mine Door Co. automatic doors mounted in certain of the main haulageways. Wood, cloth, and cinder block brattices are used where needed, the last being permanent stoppings installed for the life of the mine. There is no gas problem in any of the mines in the area and the only fire hazard is combustion of wood brattices or of diesel fuel.

Ventilation has been somewhat complicated by the large area mined and because long double-entry haulageways are being driven to connect the No. 3 shaft to the north. Diesel equipment is being used in these haulageways and return air from this part of the operation is diverted through certain worked-out areas in the mine and brought back to upcast shaft No. 2. This return air is so routed that it never passes working faces in the mine. A regular schedule of air analyses is carried on at stations in the mine where diesel equipment is in use. Mine Safety Appliance Co. colorometric detector units are used for direct check of exhaust gas from scrubber units and Orsat determinations of mine air are taken at regular stations and frequent intervals by a qualified laboratory chemist. In 2 years of diesel operation no air condition has been encountered that was even questionable.

Underground storage for diesel fuel is in an isolated room walled up on either side with concrete cinder blocks and provided with complete CO_2 protection. This room is so located that should any fire occur all gas, both from the fire or from CO_2 extinguishers, will go directly into the return air course clear of the mine workings.

Potash Co. of America

Potash Co. of America, the second operator in the area, began shipment of crude ore in 1934. Its beds are generally flat lying, and mining practice consists of setting up extraction panels averaging 1800x 1200 ft, with rooms and breakthroughs on 65-ft centers. Rooms are driven 28 ft wide, leaving 37-ft sq pillars. This results in an initial mining extraction of approximately 65 pct and practically no timbering or roof bolting is required.

Undercutting with 9-ft shortwall machines is done using standard tungsten carbide undercutter bits, the cut being made in the salt bed immediately below the bottom of the ore. Some drilling is done with auger type post-mounted coal drills, but the greater part is done with a drill jumbo developed by the company. This pneumatic tired jumbo mounts two drills, each on an independently operated arm, and is capable of drilling at a rate of 5 fpm with one operator on each drill. Holes are drilled to an average depth of 10 ft and varying hole patterns are used, depending on the height of the face, the average round having 30 holes. Ammonium nitrate explosives and millisecond delay primers are used. The bottom row and the lower half of a center V-cut pattern is fired first with the following order of firing progressing out and up with the top rib holes being fired last. Semipermanent blasting lines are installed in working panels and all the loaded faces in a working section are fired simultaneously from a central switch at the end of each shift after all of the men have been checked into the mantrip.

Joy machines load rubber tired shuttle cars which carry ore from the faces to cross panel conveyor belts which in turn load into 6-ton, 42-in gage, ro-

tary dump type cars. Ore under the rotary dump pocket is carried through a primary crusher and placed in skips by automatic loaders. Motive power is all electric, with both trolley and combination trolley and battery locomotives in service.

Two types of continuous miners are used at this operation, one of the company's own design, the other a Joy coal type machine.

Primary power is taken underground at 2300 v ac and at 12,470 v and is transformed to 220 and 440 v ac, the latter used on continuous mining equipment. Power is also converted to 250 v dc by motor-generator and mercury arc rectifier for trolley use.

Ventilation at this operation makes use of underground fans, air being drawn down through No. 1 shaft and discharged through No. 2 shaft. A third shaft has been sunk at this operation to the south of the present mining area. In sinking this 15-ft circular two-compartment shaft bad quicksand conditions were encountered, and it was necessary to freeze overburden above the salt to a depth of 360 ft before work was started. This shaft is also used for ventilation, air being drawn down one side and discharged through the other.

International Minerals & Chemical Corp.

The International Minerals & Chemical Corp., the third company to begin operations in the area, began production in 1941. This company is operating at two levels, mining in langbeinite ore on the 850-ft level and in sylvite ore on the 900-ft level. The 850-ft level is serviced by shafts No. 1 and No. 2 and is connected to the 900-ft level by a slope equipped with a belt conveyor.

On the upper level the main entry system consists of three parallel entries, each 20 ft wide and run on 52-ft centers. Panel entries of the same dimension, in pairs, are turned both ways off the main entries, at right angles, at predetermined distances along the mains. Rooms are driven both ways from the panel entries at right angles and breakthroughs are turned off the rooms leaving pillars 33 ft sq, and rooms and breakthroughs 36 ft wide. Mining heights are from 6 to 7 ft.

Faces are drilled, undercut, and blasted in a manner similar to those described for the other companies. Loading machines place the broken ore into shuttle cars hauling to any of several ore passes extending from the 850-ft level down to the 900-ft level. Here the ore is drawn out of chutes into mine cars which transport it to the No. 1 hoisting shaft. All haulage on the 850-ft level is by means of rubber tired shuttle cars equipped with trolley poles and cable reels. Present extraction within a panel amounts to approximately 77 pct with no pillar recovery having been conducted on the upper level.

Hoistman at International Minerals & Chemical Corp. operation has full view of shaft collar through plate glass window.

The 900-ft level is divided into two parts, one of which is serviced by shafts No. 1 and No. 2 while the other is serviced by shafts No. 3 and No. 4.

The general layout of the 900-ft level is approximately the same as that of the 850-ft as to arrangement, panel entries, rooms, and breakthroughs. On this level the mining heights vary from 6 to 9 ft and the ore is mined by the drilling-undercutting-blasting method or by the use of continuous miners. The ore is transported in rubber tired cable reel shuttle cars from face to mine cars. On the lower level pillars measure 34x42 ft with rooms and breakthroughs 36 ft wide, giving an extraction of 74 pct within the panel area on first mining.

Beginning in 1948, pillars were mined on the 900-ft level and this has been conducted intermittently to date. Total extraction in these areas amounts to 92 pct and convergence has been quite gradual. Careful studies are being made of both convergence and the lowering of the back in mined-out areas.

Joy jumbo drills similar to those at the U. S. Potash Co. are being used, and after a long test period are now proving satisfactory. The use of continuous mining machines is still in the experimental stage.

Haulage is done on a 42-in. gage track in 6-ton rotary dump mine cars and recently two 20-ton trolley locomotives have been connected to operate as a single 40-ton unit for use on the main line. Scrubber-equipped diesel powered bulldozers are extensively used underground for clean-up and blade work. Fork lift trucks and self-propelled movable cranes are also in use underground.

Longhole drilling and blasting has been successful in construction of ore passes between levels.

Recent innovations in hoisting have been worked out at this property with a new remote control automatic system in service at the main shaft.

Duval Sulphur & Potash Co.

Fourth company to start operations was the Duval Sulphur & Potash Co., working at 1425 ft. They began shipping a refined product December 1951.

This company uses a three-entry system, with the main entry 24 ft wide and the two outside entries 20 ft wide. Pillars between entries and panel sections are 100 ft wide, rooms are driven 28 ft wide on 84-ft centers, and connecting breakthroughs 28 ft wide are turned on 70-ft centers. Extraction within a panel area is 60 pct with an overall mine extraction of approximately 50 pct. Convergence is closely studied, but during the short period the mine has been in operation little data has been assembled.

Mining follows the drilling-undercutting-blasting cycle. Hydraulically driven rubber tired drill jumbos similar to those used in the U. S. Potash Co. and International Minerals & Chemical Corp. operations are followed by shortwall mining machines using tungsten tipped bits and 9-ft cutter bars for undercutting. These machines move from face to face on rubber tired tractors using cable reels and trolley poles.

Scrubber on diesel engined Jeep at Southwest Potash is mounted in front of radiator. Seats and steering columns were lowered for mine use.

Blasting uses ⅞x8-in. powder detonated with millisecond caps. Caps and powder are transported in rubber tired tractors to working areas and charges are fired by condenser discharge blasting machines. Broken ore is loaded into 10-ton rubber tired shuttle cars with conventional Joy crawler-mounted loaders. Two types of shuttle cars are in use, one of standard cable reel and trolley type and the other a diesel electric scrubber-equipped unit.

All main line haulage is by conveyor belt. Shuttle cars discharge onto an elevating drag conveyor which in turn discharges into a single roll crusher, which sizes ore to 5 in.; the crusher discharges onto a 30-in. belt operating at 450 fpm. At the present time there are three runs of main haulage belts totaling 3000 ft.

Ventilation is by two underground Axivane mine fans pulling air down through the mine hoisting shaft and discharging it through the No. 2 man and material shaft. Ore is hoisted in two 6-ton bottom dump skips operating in balance at rope speeds of 1150 fpm. Men and materials move at 850 fpm.

Utility haulage is by both battery powered and diesel powered trucks or jeeps and all diesel units are equipped with chemical type exhaust scrubbers.

Power is taken underground through mine shaft power cables at 4160 v and portable mine power centers reduce the voltage to 440 v at the working face. All 250 v dc is produced by selenium rectifiers.

Southwest Potash Co.

This company, last to begin production in the field, is mining on one level 890 ft below the surface. Rooms and breakthroughs are driven 32 ft in width on 112-ft centers, leaving pillars 80x80 ft. This practice results in 50 pct extraction on first mining and plans call for retreat operations in the future that will trim the pillars, giving an additional 25 to 35 pct extraction, depending upon ground conditions. Both five and six-entry systems are in use on haulageways. In all cases the entries are 24 ft wide, 70 ft center to center, with breakthroughs located every 112 ft center to center, which leaves a pillar 46x88 ft.

Since this company has only been in production since October 1952 a small area has been mined, and evidence of ground movement is not apparent.

Conventional coal mining equipment is used in mining, undercutting being done with Joy 7B machines handled on 32 T trucks and a Joy 10 RU is in use for trimming. All drilling is done with Joy CD-35 jumbo drills which are hydraulically operated. One of the drills has been modified for the use of compressed air and hollow steel in the drilling and cleaning of holes, while the others use standard auger steel. Blasting practice at the operation is similar to that at all of the other properties.

Loading is done with Joy loaders and Joy 60-E7 and Joy E-16 shuttle cars. The 60-E7 has a capacity of approximately 8 tons of potash ore with a tramming speed of 3.8 mph. This car is 54 in., overall height and 24 ft long, and uses both cable reel and overhead trolley for operation on 250 v dc. The 60-E-16 is a relatively new type of car, also equipped with trolley and cable reel, and has an adjustable elevator discharge which permits direct loading into mine cars without the use of an elevating conveyor. These machines handle from 9 to 10 tons of ore at a speed of 2.8 mph and the original cars of this type in use at this property were equipped with dual rear wheels. Later models are single wheel equipped.

Haulage to the shaft is by means of Watt mine cars having a capacity of 16 tons of potash ore. These cars are equipped with automatic couplers and are hauled with 15-ton Westinghouse locomotives having a drawbar pull of 7500 lbs at 8½ mph. Track gage is 48 in. and 80-lb rail is used on the main line. An 8-ton Goodman locomotive with a rated drawbar pull of 4000 lbs at 6½ mph is used for the handling of supplies. In the handling of ore, 6-car trains are now hauled with a single Westinghouse locomotive, but plans call for 12-car trains using two Westinghouse units hooked in tandem.

At the foot of the shaft, cars are carried through a Link-Belt rotary dump, the ore passing through a Ross chain feeder to a 36x54 in. single roll Jeffrey crusher which reduces the product to 6-in. size. Discharge from the crusher goes into either salt or ore pockets of 200 and 550 tons capacity respectively, and is carried to skips by automatic loaders. Skips are bottom dump units equipped with rubber tired wheels running on guides. Present skip capacity of 6.6 tons can be increased to 10.5 tons in the future.

The ore hoist is a Nordberg double-drum machine equipped with a 500-hp motor, and provision has been made to add an additional 500-hp motor if needed. Present rope speed is 1000 fpm. A Stearns-Roger 400-hp double-drum hoist used at the No. 2 shaft for handling both men and material.

From the main working level to the bottom level of the shaft a Nock & Garside passenger elevator has been installed in order to facilitate operations.

There are two shafts at this property located 400 ft apart. Both are circular and lined to the top of the salt with concrete. No. 1 ore shaft is 15-ft diam with two hoisting and one manway compartment. The No. 2 shaft is for handling of men and materials and is 20-ft diam, divided into two compartments by a 9-in. concrete wall. The two cage and manway compartments are located in one half of this shaft, leaving the other half free of obstruction for use as an exhaust airway. An Axivane fan with a maximum capacity of 174,000 cfm at 3.37 in. water gage is installed on the surface and serves as an exhaust fan drawing air through the airway in the No. 2 shaft. The airway compartment is also used for a second purpose. When equipment too large for the cage compartment is to be lowered into the mine a concrete cover slab over the airway is removed, one of the regular cage ropes is disconnected and run over a third sheave on the headframe.

A number of pieces of scrubber equipped diesel equipment are in use at this property. Two standard Willys jeeps powered with Waukesha diesel engines are used for transportation of explosives and a third has a small bulldozer blade for clean-up work.

Drilling Practice In Swedish Mining

by Ingvar Janelid

Drill jumbo at Kiruna uses two chain-fed drifters for drilling fanholes in top slicing. The drills are arranged to turn around a horizontal shaft and can be placed at any angle in relation to the shaft so the drillhole will have the desired direction.

DURING the last ten years, in the effort to save manpower and costs, methods of drilling and blasting in Sweden have changed and developed in a revolutionary manner. These developments have been accompanied by extensive alterations in methods of tunneling and in mining technique.

Since the end of the 1940's there has been a 100 pct change-over in Sweden to the use of tungsten carbide tipped drill steel. Both investigations and practical results have shown clearly that a tungsten carbide chisel bit fastened directly on the drill steel is the most economical for Swedish conditions. This applies to drill steel up to the longest size it is practical to handle. In terms of drilling footage, durability of the drill steel and the tungsten carbide bit is generally the same. In this respect, therefore, a detachable bit offers no advantage over integral steel. Transportation of integral steel to the grinding plant, instead of detachable bits only, involves heavier work, but this is counteracted by placing grinding plants closer together or by grinding at the working place itself. The drilling rate with integral steel is higher, the trouble of changing bits is avoided, and the difficulties which always arise with joints are eliminated.

At present steel dimensions are usually 7/8 in. with a shank 4¼ in. long, whereas the international standard shank was formerly 3¼ in. The longer shank renders possible a better guide control of the steel and consequently longer life for the rotation chuck and the water-flushing pipe. After extensive experiments and investigations, agreement has been reached in Sweden on certain series of standards, shown in Table I. Other steel dimensions are, of course, available for special purposes. The standard drill-steel set begins with a 34-mm diam and has a length interval of 2 2/3 ft. On the other hand, for ordinary drifting it has been proved more economical to use greater length intervals on the steel, so only one steel change is required for a 6½-ft round. Moreover, owing to the relatively close hole spacing necessary in a drift round, it has been possible to reduce the diameters of the tungsten carbide bits. This results in faster and cheaper drilling. As shown by the table, the lengths of drill steels for normal drifting are 3¾ ft and 7½ ft, with 29 and 28-mm diam bits.

During the last few years operators have begun to use ¾-in. drill steel in place of the 7/8-in. drill steel chiefly employed earlier. This is a valuable development in drilling technique, particularly in view of

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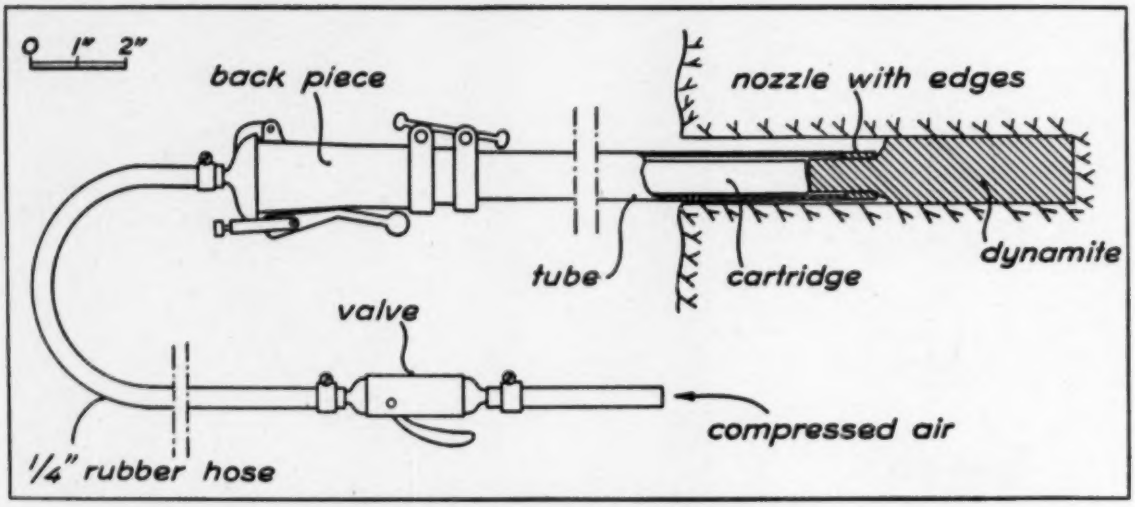


Fig. 1—Diagram of pneumatic apparatus for loading boreholes.

Table I. Standard Tungsten Carbide Tipped Steel Used in Sweden

Integral Steel						Flexible Steel	
⅞ In. Hexagon							
Normal Series		For Drifting		¾-In. Hexagon		½ x 1 In.	
Length	Bit Diam, mm	Length	Bit Diam, mm	Length	Bit Diam, mm	Length	Bit Diam, mm
2 ft 7 in.	34	3 ft 8 in.	29	1 ft 4 in.	29	2 ft 7 in.	34
5 ft 3 in.	33	7 ft 4 in.	28	2 ft 7 in.	28	5 ft 3 in.	33
7 ft 10 in.	32			5 ft 3 in.	27	7 ft 10 in.	32.5
10 ft 6 in.	31			7 ft 10 in.	26	10 ft 6 in.	32
13 ft 1 in.	30			10 ft 6 in.	25	13 ft 1 in.	31.5
15 ft 9 in.	29			13 ft 1 in.	24	15 ft 9 in.	31
						18 ft 4 in.	30.5
						21 ft	30
						23 ft 7 in.	29.5
						26 ft 3 in.	29
						28 ft 10 in.	28.5
						31 ft 6 in.	28

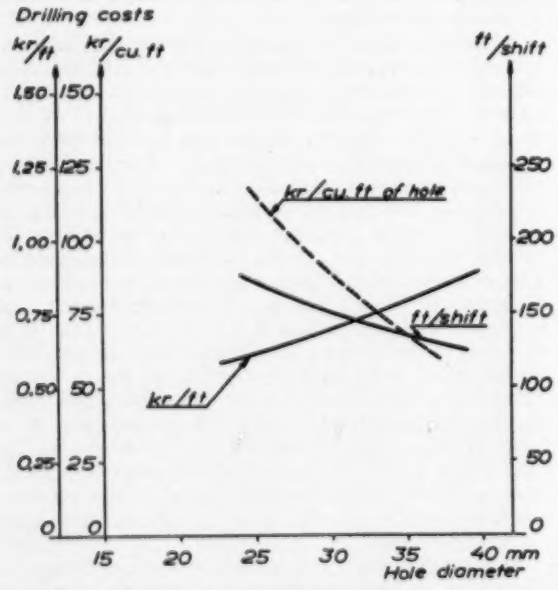


Fig. 2—Effect and costs of drilling in hard iron ore.

the fact that larger drill steels are used in countries other than Sweden, especially in America. Steel dimensions in Sweden at the present time are of the following proportions: 2 pct 1 in., 85 pct ⅞ in., and 13 pct ¾ in., with steady increase in use of the smallest dimensions.

With ¾-in. steel smaller bit diameters are used, beginning with 28 mm (see Table I), which of course means a reduced charging volume, reckoned per drilled foot. In spite of this, the smaller sizes have proved in many cases to be economically preferable in hard and abrasive rock. When an investigation is made, for instance, of how the charging volume is actually used in a 36-mm drillhole that can hold about 0.94 lb dynamite per ft, it is discovered that a normal charge comprising 25-mm cartridges, loaded with a stick, gives about 0.34 lb of dynamite per ft of drillhole. In other words, only about 35 pct of the drillhole volume is utilized, which undoubtedly will surprise many people. If charging is done more carefully the hole spacing can be retained and a smaller drillhole diameter adopted. To obtain a satisfactory charging density two different methods have been employed: 1—charging with 5-ft long cartridges, which have a larger diameter and fit the drill hole better, and 2—charging by means of a special pneumatic apparatus manufactured by the Nitroglycerin AB in Stockholm. The following is a practical example of the charge per foot obtained in 36-mm boreholes at the Malmberget mines:

Loading normal cartridges with wooden stick	0.34 lb dynamite per ft drill hole
Loading 5-ft long cartridges of larger diameter	0.58 lb dynamite per ft drill hole
Loading by means of pneumatic apparatus	0.81 lb dynamite per ft drill hole

The pneumatic charging apparatus is shown in Fig. 1. The manner in which it operates is briefly described here.

The charging pipe is equipped with a back piece which can be opened and closed and through which the cartridges of explosives can be inserted. The diameter of the cartridges must be 1 to 2 mm smaller than the internal diameter of the pipe so a current of air can pass between the cartridges and the wall of the pipe. Compressed air is supplied through a hose connected to the back piece. A choke flange in the air-intake limits the amount of air admitted so the cartridge will not exceed a maximum speed of 33 ft per sec.

The pipe is equipped with a nozzle in the front end, the internal diameter of which is the same as the diameter of the cartridge. When the compressed air is turned on, the current of air draws the cartridges with it until the front one reaches the nozzle. The air is thereby hindered from streaming out. The pressure in the pipe rises and the cartridge is forced out into the borehole, whereupon three steel edges on the inside of the nozzle cut up the paper casing of the cartridge with lengthwise cuts. The slit cartridge can easily be packed together with the help of the charging pipe so that the dynamite fills the hole completely. The pipe is then drawn out and the next cartridge is pressed forward and packed in the same manner.

The durability of ¾-in. steel is somewhat inferior to that of ⅞-in. steel, but the wear on the tungsten carbide bit per drilled foot is considerably less with the smaller bit diameter. Use of 28-mm bits instead of 34-mm bits almost doubles drilling footage per grinding in hard rock.

In the diagram, Fig. 2, the total drilling costs, together with the drilling footage per shift, are plotted as a function of the drillhole diameter when hard ore is drilled. As shown, decreasing the drillhole diameter increases the total drilling footage per shift and decreases cost per drilled foot, but the cost per volume unit of drillhole increases. If the same amount of explosives can be packed in a smaller drillhole by improved charging methods, and the hole spacing can be retained, the total cost will be lower.

One of the most important factors in choosing the hole diameter is the frequency of boulders, which influences the costs for secondary blasting, loading, transportation, and primary crushing. The boulder frequency can be effectively controlled by close hole spacing. The advantage of using ¾-in. steel and small hole diameters is fast and inexpensive drilling. However, charging must be done carefully, preferably with the loading apparatus.

A summary of the points that are of chief importance in the choice of a suitable drillhole diameter can be expressed as follows. A large borehole gives

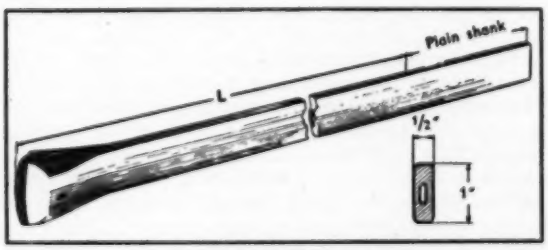


Fig. 3—Flexible drill steel.

the cheapest borehole volume, but when consideration is given to boulder frequency and possible hole spacing, for instance, in tunnels or in narrow orebodies, the hole spacing must be comparatively close. Hole diameters must not be larger than necessary for charging the calculated amount of explosives.

Use of ¾-in. steel, especially in hard rock, is steadily increasing. An examination of its practical and economic advantages in underground mining has been made by G. Nilsson, the chief mining engineer at Striberg, and by others. Among the mines which have gone over partly to ¾-in. steel are the Stripa, Garpenberg, Haksberg, and Boliden.

As previously mentioned, detachable bits have not been used in Sweden other than for long holes. A

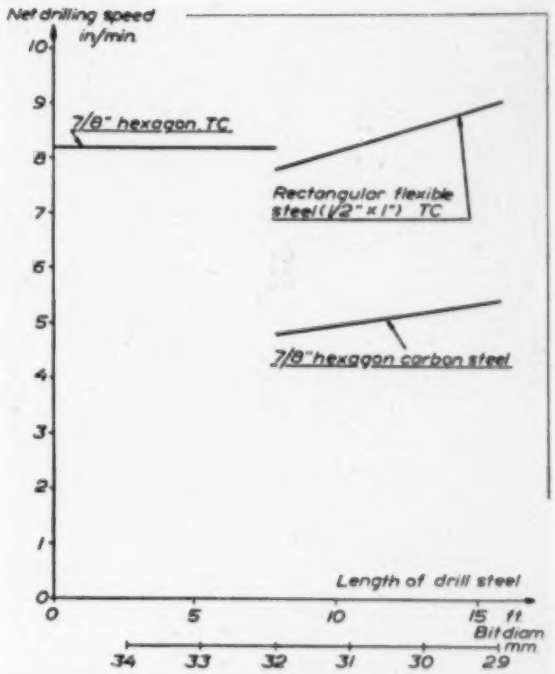


Fig. 4—Net drilling speed in iron ore with different types of drill steel. Rock drill: 2 9/16 in. with pusher.

completely new type of drill steel has been introduced for holes of 13 to 26 ft long, namely flexible steel, which can be bent both during transportation and when it is inserted in the hole. Dimensions of this steel are ½ to 1 in., see Fig. 3. The drilling rate with the same diameters of tungsten carbide bits is somewhat lower with flexible steel than it is with ⅞-in. steel.

A fair comparison of the respective drilling rates of flexible steel and extension steel is impracticable, as flexible steel requires small light machines and extension steel heavier machines with power feed.

At Grängesberg, where more than a million tons of iron ore are mined per year with top slicing, it is very important to be able to drill some of the holes longer than is possible with ordinary integral steel. At the same time, of course, it is desirable to retain the same light drilling outfits normally used. Development costs will be less because the height between slices and distances between crosscuts may be greater than if only ⅞-in. integral steel is used. Formerly, bendable carbon steel was used in Grängesberg for the longest holes, but flexible steel has now been adopted there for holes 8 to 20 ft. Fig. 4 shows the footage obtained with ⅞-in. hexagonal steel and with ½x1-in. flexible steel, both with tungsten carbide bits. The diagram also shows the footage obtained with ordinary bendable ⅞-in. carbon steel, which is not suitable for tungsten carbide bits. As is shown in the diagram, the drilling rate is very good for flexible steel and higher than for ⅞-in. steel with tungsten carbide bits, because of the smaller bit diameter.

Fig. 5 shows how flexible drill steel can be bent when inserted in a drill hole. In the near future flexible steel will probably be used widely as a complement to normal steel.

Long-hole drilling is now a customary method, especially in America; nevertheless, the following information may be of interest. Both diamond drill-

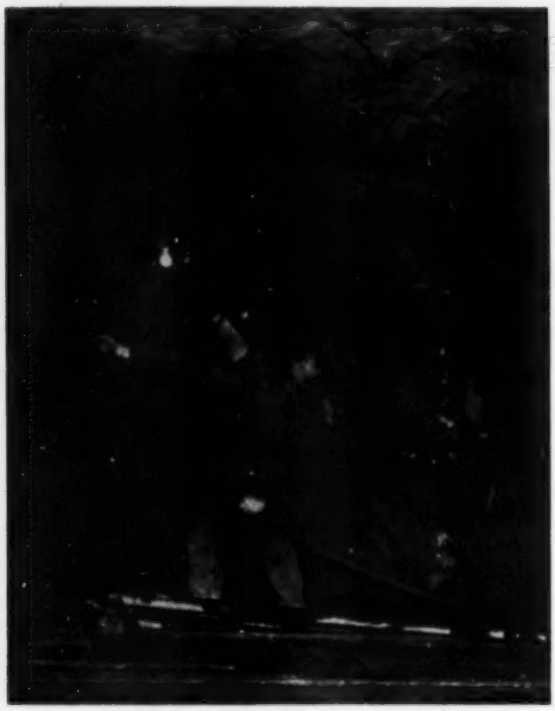


Fig. 5—The use of flexible steel in top slicing.

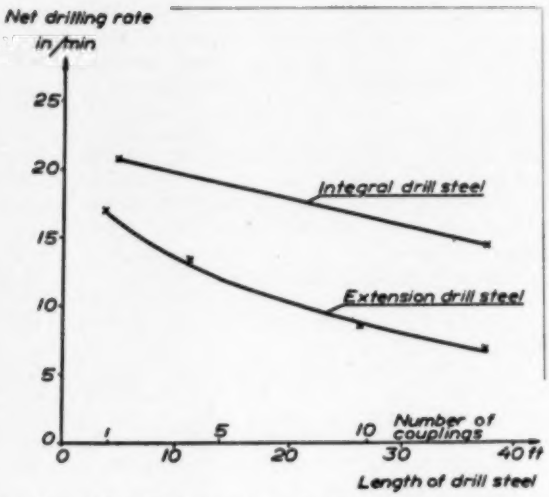


Fig. 6—Net drilling rate as a function of length of drill steel. A 4-in. drifter with chain-feed and a bit 40 mm in diam are used.

ing and extension steel (see Fig. 6) with tungsten carbide detachable bits are used for long-hole drilling in Sweden.

The diamond drill machines are driven by compressed air and are of two different types, namely, those with mechanical force feeding and those with automatic friction feeding. For drilling in hard rock the latter type has proved to be preferable as it causes less wear on the drill bits. In loose and medium hard rock noncoring bits with small diamonds are used, but in hard rock core bits are the most economical and considerably reduce diamond wear. Total footage in core drilling is decreased by reason of the necessary core removal, as well as interruptions when the core breaks. Considerably better results have been obtained through reversed water flushing, whereby the core as well as loose core fragments are pressed back into the drill rod. The flush water is forced through a special sleeve on the outside of the drill rod, or a special double-tube core barrel is used. In certain cases the drill rod is given such a large diameter that the core can be flushed back through the entire rod, and in this case core removal takes place less frequently. To facilitate the flushing out of the core compressed air is occasionally added to the flush water. The reason for this is that when the air expands while passing out of the drill rod the water draws the core as well as the core fragments along more readily. In this connection it has proved advantageous, when using hole diameters of 36 mm, to reduce the core diameter from 22 to 18 mm. Another very great advantage with reversed water flushing is reduced diamond wear, sometimes only half in comparison with customary flushing; this is due to the fact that no core fragments are pressed forward to the diamond bit.

During the last few years long-hole drilling with *pneumatic hammer* drills and extension steel has come more and more into the foreground and partly replaced diamond drilling. Drill rods, which are usually ⅞ in., have become more durable owing to the use of longer couplings, among other reasons. The threads have also been designed in a form with higher pitch, making it possible for uncoupling to be done conveniently by hand without any tools. Larger and stronger machines, such as the Atlas Diesel 4-in. BBC 41 RBL, see Fig. 7, are used for long-hole drilling. Power feeding with a compressed air motor is adopted.

When holes are drilled with extension steels a part of the energy transmitted is lost in the joints; consequently the drilling footage is lower than with integral steel. In the diagram, Fig. 6, a comparison has been made between drilling with integral steel and extension steel with the same machine. Note that a higher output is obtained with integral steel. This fact is taken advantage of to the fullest extent at working places where long drill steel can be used, as in tunnels, large spaces underground, and, of course, open-pit stoping.

In Malmberget, where a large part of the ore is mined by long-hole drilling, excellent material has been obtained for comparison between diamond drilling and drilling with extension steel. Drillholes had an average depth of 100 ft. Drilling footage per shift in ore is about 50 pct greater with pneumatic drills and extension steel, and drilling costs are 20 to 30

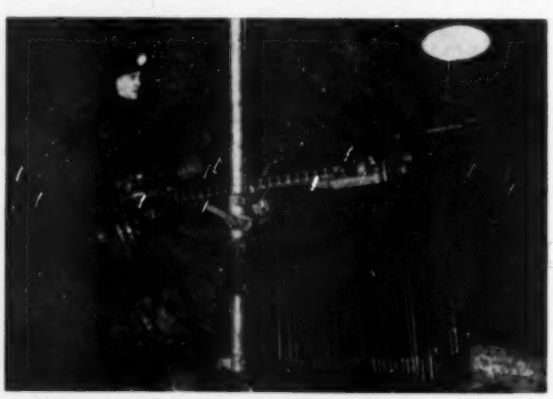


Fig. 7—An Atlas Diesel 4-in. drifter with motor feed for long-hole drilling.

pct lower than with diamond machines. With the present equipment for long-hole drilling in medium hard rock, it will be cheapest to use pneumatic drills and extension steel up to 130 or 160 ft.

Before the different types of rock drills are described attention should be called to the fact that there are drilling sites requiring relatively few holes and others requiring mass production of drillholes. In the first case the practice of one man to one machine has been accepted throughout Sweden; the simplest proof of this is that since 1948 no new stopehammers have been manufactured in Sweden, but only light rotary machines and pushers. The endeavor has been to make a simple and inexpensive machine which can be used under many different conditions. The method of using light machines and pushers is too well known in the U. S. to need further description here.

In the second case, i.e., with mass production of drillholes more or less at the same working site, power-fed drilling machines mounted on wheels or easily transported are usually preferable. Through the introduction of short delay blasting of large rounds in such operations as cut-and-fill and shrinkage stoping, these power-fed machines have come into more general use during recent years. Fig. 8, a picture of cut-and-fill mining in Boliden, shows a wagon drill with two chain-fed drilling machines, placed side by side, which are operated by one man. The footage has been increased from 180 ft with a pusher to 550 ft per manshift with the twin machines. By the use of more powerful feeding, the drilling rate has been increased from 12 to 16½ in. per min. It should be pointed out, however, that the pusher drill is not very suitable for overhead drilling.

In drifting comparative investigations have been made between a drillmobile equipped with three chain-fed drifters and a self-propelled platform in combination with three pusher drills, see Fig. 9. The drilling platform, which runs on rubber wheels and is driven by a compressed air motor, is very easily moved. On completion of drilling with the platform in the position shown in Fig. 9, the platform is moved to the opposite side of the drift. Results shown in Table II were obtained in Kiruna from a test in a gallery 10x16½ ft.

Although the drillmobile is easily moved and easily operated, equal or better results have been obtained hitherto with the cheaper pusher drills in combination with a simple drilling platform.

For drilling fanholes in a top slicing a special drill jumbo has been developed. See cut, p. 613, showing top slicing in Kiruna. Two chain-fed drills, arranged to turn around a horizontal shaft, can be

Fig. 8—An illustration of cut-and-fill mining at Boliden. The wagon drill with two chain-fed drifters, shown above, is operated by one man. With these twin machines footage has been increased from 180 ft with a pusher to 550 ft per manshift.

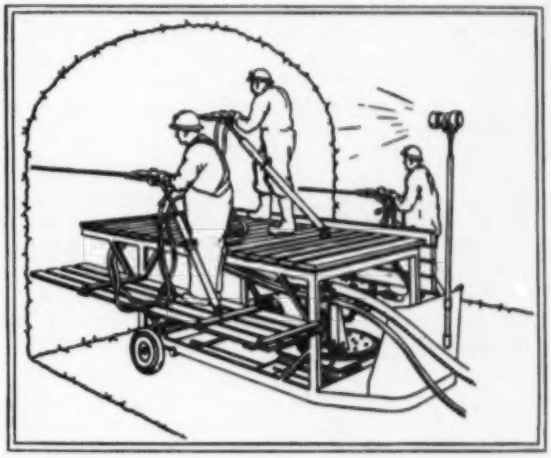
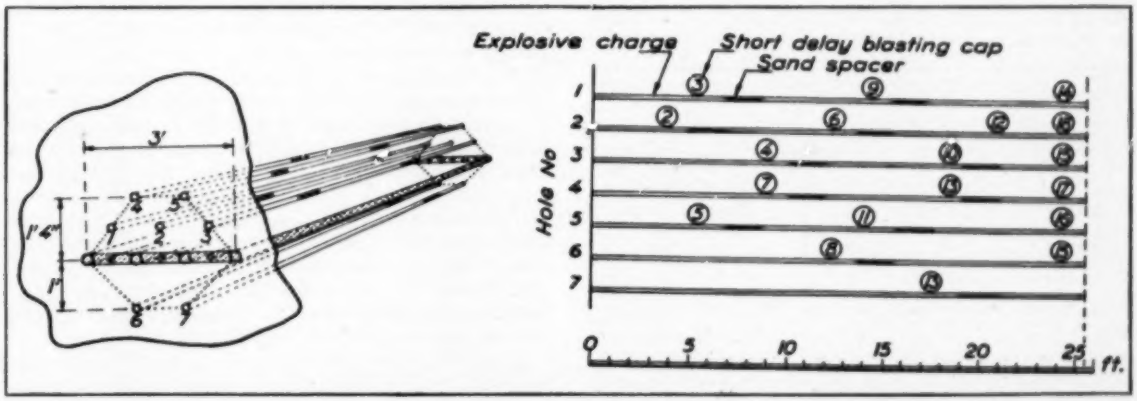


Fig. 9 (above)—Drilling platform for pneumatic pusher rock drills. The drift is 16 ft 5 in. wide and 11 ft 5 in. high.

Fig. 10 (below)—The multi-burn cut and a diagram of charges in drillholes.



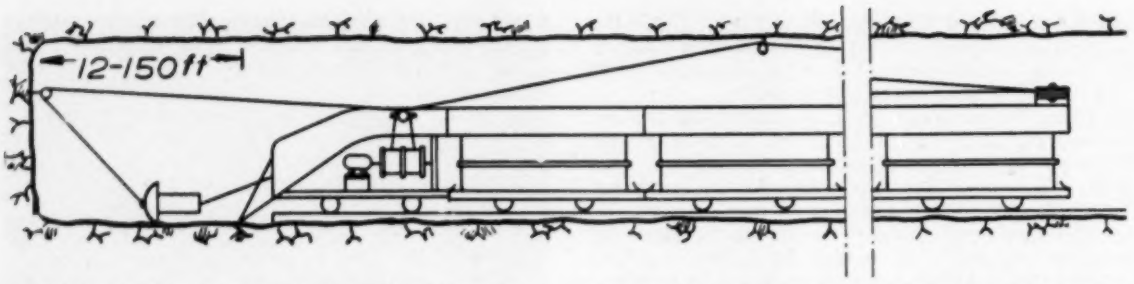


Fig. 11—Scraper equipment for small tunnels, with cars for an entire round. The scraper is drawn along flanges on top of the cars. The scraper ramp is shifted every 40 or 50 ft of advance.

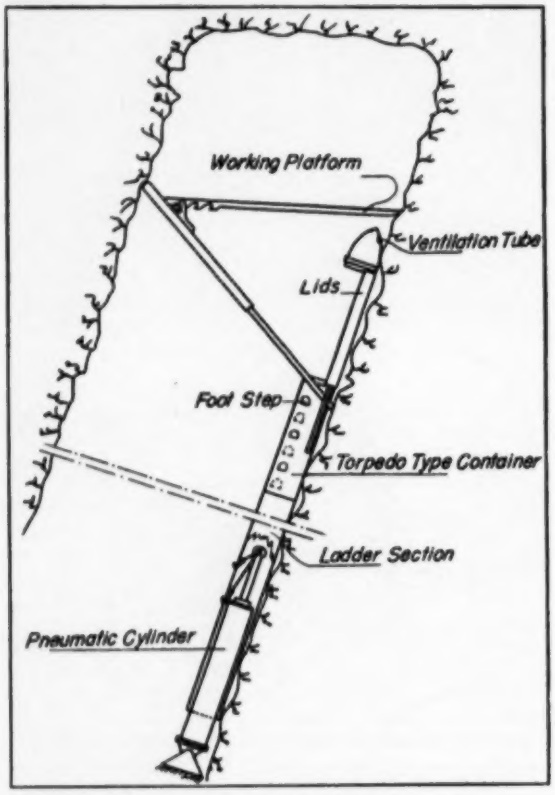


Fig. 12—Use of a steel ladder for driving raises.

placed at any given angle in relation to the shaft so the drillhole will have the desired direction.

All investigations and new ideas for raising the efficiency of drilling and blasting operations must be based on a thorough study of the most favorable utilization of personnel and machines. Results reported by different companies, summarized in this paper, have been obtained after very comprehensive time studies. The effort to render rock blasting more efficient is expedited when progress and results obtained at one place are made available to others. For this reason a collection of articles on problems of blasting is published in Sweden under the title *Manual on Rock Blasting*,[1] which is printed in four languages.

Table II. Results of Test Drilling in a 10x16½-Ft Gallery at Kiruna

Item	Drilling Platform with Three Pusher Drills	Drill-mobile with Three Hydraulically Controlled Machines
Drift, ft	840	700
Stope, cu ft	6113	742
Total working time, hr	2020	2181
Manhours for drilling per foot of advance	2.5	3.3

In every field, it is true, the cheapest products are obtained by mass production, where the setting-up time between the various working steps is the shortest possible per unit produced. In rock blasting, which is a combination of completely different forms of work, an attempt is made to achieve high efficiency of drilling and blasting as well as of loading. However, the work must be so arranged that the working cycle is as long as possible. This can be brought about partly by drilling long holes and partly by drilling a large number of holes for each round.

Practical Examples

In cut-and-fill mining in Boliden, Fig. 8, it has been possible to increase the mining results considerably by drilling very large rounds. It is estimated that in shrinkage stoping in Kiruna it may be possible to increase capacity as much as ten times by blasting large rounds rather than by using the old method of blasting. Long-hole drilling at Malmberget has been described in an earlier paper.[8]

To obtain a long working cycle in drifts and tunnels the advance per round must be increased. However, the advance per round depends wholly on the length of the cut and therefore much experimenting has been undertaken to solve this problem. Two different cuts have been tried: 1—the burn cut or Michigan cut with large diameter center holes, and 2—a special type of burn cut with divided charges in every hole, together with short-delay blasting.

Originally the method employing short-delay blasting was done with the charges divided into only two parts per hole. A narrow cut of about 13 ft deep could be produced. Later on Langefors of the Nitroglycerin AB developed a system for dividing the charges, whereby cuts up to 23 ft deep could be obtained. The principle of this method, which is known as the *multi-burn cut*, is presented in Fig. 10. The four large drill holes in the center (diam 80 mm) are not charged, and the three smaller holes (34 mm) between the larger ones have column charges and are fired first to produce an opening in the middle of the cut. In the other drill holes, Nos. 1 to 7, the charges are divided, according to a predetermined system, by sand spacers of about 2 ft long. Blasting the divided charges with short-delay caps placed in a predetermined sequence breaks out the rock a little at a time. The method has recently been used very successfully in blasting out underground air raid shelters and oil tanks.

When the Michigan cut with one or more large center holes is used it has been found that the large

Fig. 13—Working platform and torpedo containers with lids open, seen from underneath.

holes must be of 4 to 6 in. diam if good results are to be obtained. Pneumatic hammers are used to drill the large holes directly or to ream out normal smaller holes. Several different types of drill bits have been tried for this purpose.

A necessary condition for using the above-mentioned burn cuts with parallel and closely placed holes is that the drill holes must be correctly directed from the beginning and drilled straight. At the present time the possibilities for this seem to be satisfactory.

In all drifting it is essential to a rapid advance that the work be organized so that all setting-up times and delays are as short as possible. Boliden Co. has constructed a type of scraper equipment, shown in Fig. 11, which makes quick loading and transportation possible in drifts with a cross-section of about 50 sq ft or more. The wagons are so constructed that the scraper slides along their upper edges and fills the whole train, beginning with the wagon which stands nearest the scraper. The scraper ramp is placed first, 13 to 20 ft from the drift face, and is allowed to remain there until the scraper length is about 160 ft. All drilling is done with pusher drills, which are easily moved away to a protected place behind the scraper hoist during blasting. The advance with this outfit has amounted to 23 ft per day of two shifts, five men to the shift, in a tunnel area of 97 sq ft. Two men handle the scraper. The rock is first removed from the face to enable the other three men to start drilling. Very thorough comparative investigations in connection with this and other methods have been undertaken by V. Wanhainen of the State Power Board in Sweden. Results will be published in the *Manual on Rock Blasting.*

Another novelty which may be mentioned here is a steel ladder, Fig. 12, used in driving raises. The ladder can best be employed in inclined raises deviating at least 20° from the vertical. The lower part of the steel ladder consists of a powerful air cylinder, which can push up the whole construction so that a new section can be added. A working platform is arranged over the top of the ladder. The upper section of the steel ladder consists of a strong torpedo-shaped cylinder with lids. The platform planks and drilling equipment can be kept in this cylinder during blasting. The semi-cylindrical sheet metal tube serves as a ladder owing to the provision of notches formed in the metal. Air and water hoses and electric cables run inside the tube. The entire construction is so strongly dimensioned that it will not be seriously damaged by falling rocks.

In a comparison of the new method of driving raises with the older, more conventional method using timbering, it is found that:

1—The setting-up time for drilling a round decreases from 2½ to 1¼ hr.

2—The cost of material for a ladder 130 ft high is 4500 Swedish kronon. The ladder can be used for at least five raises. This means a cost of 900 Swedish kronon per raise, in comparison with 3500 Swedish kronon per raise for timbering.

3—The saving of time in raising is considerable, since both the work of timbering and removing the timber afterwards is eliminated. The pipes are simply led through the steel ladder, and ventilation takes place quickly because fresh air can be brought near the top of the raise.

4—Safety is increased when this steel ladder is used.

Summary

In hard rock ¾-in. drill steel and small diameter bits have been shown to be more economical than normal ⅞-in. steel. Flexible steel is used to great advantage instead of extension steel when holes between 13 and 26 ft are drilled. It is more economical to use extension steel than diamond drills in drilling holes up to 100 or 130 ft in medium-hard rock. Small pusher drills are the usual type, but in long-hole drilling and in mass production of holes in a limited area the larger 4-in. machines with chain feed are used. By means of special blasting methods, great progress in tunneling is being made with long advances per round. A mechanical steel ladder has been developed for raising which reduces the required working time, increases the production per shift, and insures greater safety.

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The Liquid-Solid Cyclone as a Classifier In the Closed-Circuit Grinding of Concentrates

by F. M. Lewis and E. C. Johnson

Used as a classifier in a plant expanding capacity or changing to closed-circuit operation, the liquid-solid cyclone offers the advantage of being adaptable to existing conditions. This paper presents the costs involved and experience gained from operating a unit of this kind.

BY now application of the liquid-solid cyclone to various classification problems in the chemical and metallurgical fields is more or less familiar. A less publicized application receiving wider consideration as time goes on is its use as a classifier in closed-circuit grinding operations. This paper presents the costs involved and the experience gained from operating a unit of this kind.

In May 1951 the Tennessee Copper Co. installed in its London mill at Copperhill, Tenn., a liquid-solid cyclone in closed circuit with a 6x12-ft ball mill. The circuit in which this cyclone is used is the regrind or secondary grinding circuit of a copper flotation plant. Originally it consisted of a 7x1-ft conical ball mill in closed circuit with a bowl classifier. Changes made in the primary grinding circuit of the mill necessitated a regrind circuit of greater capacity. The bulk concentrate to be ground was raised from 900 or 1000 tpd to 1200 or 1300 tpd, and to accommodate this increase a 6x12-ft ball mill which had been in the primary grinding circuit was moved into the regrind circuit. When this was done it was found that the classifier was too small to give efficient operation. Space in the plant was at a premium, and since use of the cyclone offered considerable economy the installation shown in Figs. 1-3 was made.

The unit installed is a 24-in. diam cyclone classifier with a 20° cone angle. Diameter of the vortex finder is 8 in., the feed entrance area 20 sq. in. Maximum diameter of the adjustable apex valve is 6 in. and minimum diameter approximately 3.5 in. To refer again to Figs. 1 and 2, the cyclone* is mounted horizontally, and the underflow, or sands product, discharges directly into a 6x12 ball mill. This mill has a speed of 21.9 rpm and is powered by a 200-hp motor. It is charged with 18 tons of 1-in. balls. The overflow, or fines, passes by gravity directly to the copper flotation plant. The ball mill discharge and the new feed combine in a sump from which they are sent to the cone by an 8x6 SRL pump at a rate of 497 gpm. Pressure at the cyclone is 5 psi.

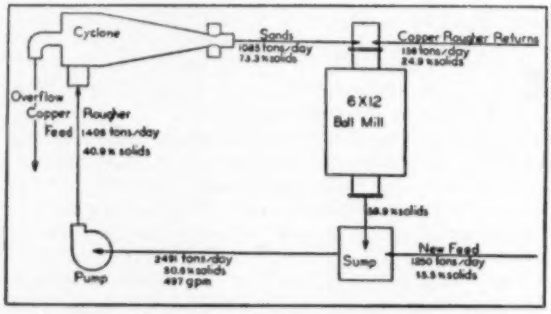

Fig. 1—Closed-circuit grinding of copper flotation feed using 24-in. cyclone.

For reasons dictated by the nature of the ore treated, particularly the bonding of fine grains of chalcopyrite to pyrrhotite, the froth from the second cell of the copper rougher circuit is returned to the regrind mill. This flow, which somewhat complicates the standard closed-circuit calculation, is seen in Fig. 1 to be 156 tpd of solids. This combines with the cyclone classifier underflow to constitute the ball mill feed.

The requirement of the regrind product is that it be 77 to 80 pct −200 mesh. The liquid-solids cyclone operating in conjunction with the 6x12-ft mill adequately met this requirement. Of primary importance is the fact that this arrangement provided sufficient classification capacity to replace the undersized classifier and was capable of building up a circulating load to 87 pct, large enough to give an efficient grind. In this instance the circulating load is taken as the ratio of sands to new feed.

Any comparison of performance between this liquid-solid cyclone and the replaced classifier would of course be unfair, since the bowl classifier was

* The cyclone discussed in this paper is the Dorrclone, manufactured by the Dorr Co., Stamford, Conn.

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admittedly undersized, but the increase in grinding efficiency, Table I, when the cyclone was placed in operation is of interest.

Table I. Improvement in Regrind Circuit After Change from Undersized Classifier to 24-In. Cyclone

Machine	Period of Time Over Which Averages Were Made	Raw Feed: −200 Mesh, Pct	Raw Feed: TPD	Tons −200 Mesh Per Day	Ball Mill Hp	HP Per Ton of −200 Mesh Made
Classifier	Jan-Apr 1951	63.9	1286	104	155	1.49
Cyclone	Year 1952	65.8	1286	177	131	0.74

Screen Analysis

Mesh	Average Feed	Cyclone: Overflow	Cyclone: Underflow	Classifier: Overflow	Classifier: Sands
100	1.3	0.2	2.9	1.6	13.5
150	18.9	4.9	37.1	10.8	56.3
200	37.4	17.0	63.9	26.4	79.2
−200	62.6	83.0	36.1	73.6	20.8
Solids, Pct	50.6	40.9	73.3	41.1	82.7

The figure which draws immediate attention is the reduction from 1.49 to 0.74 hp consumed per ton of −200 mesh material produced; the 50 pct reduction speaks well for the proper sizing of classifiers in circuits such as this. The accompanying 70 pct increase in the quantity of −200 mesh material produced with the 15.5 pct decrease in total ball mill horsepower bears this out.

The power reduction shown in Table I can be attributed to several factors. With the undersized classifier in the circuit it was not possible to build up the necessary circulating load of sands to the mill. This caused the density in the mill to be low and at the same time increased detention time. The increased detention time was primarily a metallurgical factor in that it caused the mill to go acid, greatly affecting the copper recovery. Attempts made to correct these conditions included sending the raw feed directly to the mill and increasing the ball load. (The above classifier data were collected after the ball load was increased.) Installation of the cyclone with the subsequent increase in circulating load and grinding efficiency permitted a reduction in ball load which accounts for the decrease in power.

Comparing the screen analyses of the two indicates that the bowl classifier provided a cleaner sand. Decreasing the diameter of the cyclone apex valve would have increased the underflow percent solids,

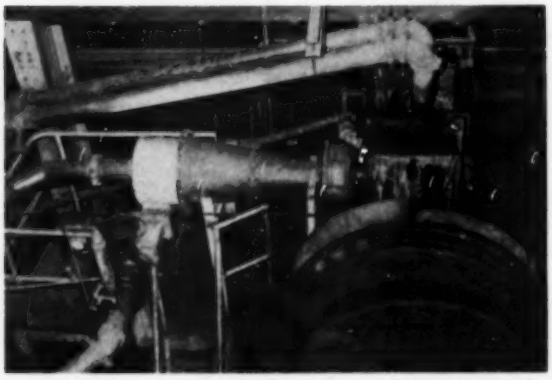

Fig. 2—View of cyclone installation at Tennessee Copper Co., Copperhill, Tenn.

Fig. 3—View of cyclone classifier, taken from overhead crane, showing small space occupied by unit.

making it possible to approach the classifier rake product in this respect.

Operating the cyclone, in this instance with the apex valve wide open to provide the greatest possible circulating load, gave a sands product higher in −200 mesh material but at the same time provided an overflow which was believed to function best in the flotation circuit. Production of a grind which provided the greatest possible yields in this flotation circuit was, after all, the goal.

Operation Costs and Wear

Pumping 497 gpm of a 50.6 pct solids slurry through a device such as this liquid-solid cyclone will, of course, produce wear on at least some of its parts. As originally supplied, the cyclone was completely rubber-lined, except for the feed chamber. Since then this section has also been rubber-lined. In this operation the vortex finder has been the part that has shown the most wear. Life of a vortex finder has varied from 100 to 150 days. The feed and conical sections have an estimated life of three years. The apex valve shows no sign of wear. Using only 5 psi feed pressure at the cyclone helps considerably in keeping the cyclone maintenance low.

Table II compares operating costs of the liquid-

Table II. Comparative Daily Costs of Operating and Maintaining a 24-In. Cyclone and a Sedimentation-Type Classifier

	Cost, $
Cyclone	
Maintenance: pump	
Impellors, suction and gland side liners, casing plate	2.24
Labor	0.04
Cyclone: vortex, head and cone, apex valve	0.41
Power, $0.0044 per kw-hr	0.83
Total	3.52 per day
Classifier	
Maintenance: rakes, screw conveyor, scoop feeder	1.21
Power	
Scoop feeder	0.39
Classifier	0.32
Total	1.92 per day

solid cyclone and sedimentation-type classifier performing in the closed-circuit described here. Although the cyclone installation costs 83 pct more to operate than the sedimentation-type unit, in many cases the difference in initial investment will justify use of the cone. Furthermore, in a plant that is expanding its capacity or changing to a closed-circuit operation the cyclone offers the advantage of being adaptable to existing conditions. It requires less floor space and in many instances can be mounted directly over the grinding mill.

Fig. 1—The rod charging machine used at International Nickel's Copper Cliff concentrator loads 34 rod mills three times a week. With this machine three men accomplish in less than 2 hr a task that once required eight men working 4 hr.

Methods of Charging Rods and Balls Into Grinding Mills

by Oscar Johnson

The industry has been canvassed for information on methods of handling grinding steel at milling plants, an important subject overlooked in most descriptive articles on milling plant arrangements. The data collected are offered in this paper as a guide to designers and planners who have loading and storage problems to solve.

WITH capacities of milling plants expanding from a few hundred tons per day to many thousand, replenishment of grinding media is an important phase of mill operation. Information on this aspect of milling procedure, solicited from several mining companies, is summarized here.

At **International Nickel's** Copper Cliff concentrator the normally strenuous job of changing rods is considerably simplified by the use of the Garrow rod charging machine, Fig. 1. The overhead crane, Fig. 2, brings a bundle of rods, weighing four to a ton, to the loading platform of the machine, positioned in front of the mill. The rods roll one by one down the slight incline of the platform onto a conveyor which sends them into the mill.

A modified version of the Garrow machine, Fig. 3, is used at the Federal mill of St. Joseph Lead Co. An overhead crane places the portable steel structure in position in front of the discharge end of any one of the five 9x12-ft rod mills. It then raises a bundle of about twenty 3-in. rods to the discharge platform of the charging machine. The rods are 11 ft 7 in. long and weigh about 278 lb. By tripping a lever the operator allows one rod at a time to roll onto the inclined rollers. A slight push by the operator sends the rod smoothly into the mill.

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The **Union Miniére du Haut Katanga** rod charging machine, Fig. 4, is mounted on a pair of wheels at the forward end with swiveling castors at the back for steering it to position for use or storage. Wheels are equipped with locking brakes to maintain the machine in position while it delivers rods to the mill.

The device is made in two parts. The first consists of the base, which carries the supporting wheels, grooved rollers, and drive. The other part serves as the rod deck, which can carry up to six 3-in. x 12-ft rods. A short boom built integral with the base reaches through the mill trunnion and delivers the rods into the mill barrel.

Three grooved guide rollers are provided to receive the rods from the sloping charging deck. One rod at a time is fed to the rollers and thus delivered into the mill. Two of the rollers are driven by 1½-hp motor through a *V*-belt drive. The third roller is driven off the first by a single *V* belt in a groove below the rod groove and on the same center line. Rods are delivered to the charger by an overhead crane in bundles of three to six as needed.

The power is supplied by cables plugged into power outlets, suitably located near the rod mill discharge end.

The **Oliver Iron Mining Co.** uses a rod charger, Fig. 5, suspended from a monorail by cables. It is constructed of structural steel and has two decks, each capable of carrying five rods of 4-in. maximum diameter. The rods ride in grooved free-turning rollers. Legs extending down from the mill end of the mechanism act as supports when the unit is ex-

tended into the discharge trunnion liner. When the mechanism is placed in the trunnion, the projecting end of the charger is elevated by a chain-and-sprocket lifting block providing slope to the charger. A lever for each deck allows the operator to release five rods at a time and gravity carries them into the mill interior. It is found that pushing the protruding ends away from the axial center line of the mill will carry the rods all the way into the mill, thus preventing their tangling by catching in the space between the rods which constitute the normal charge. Only one man on the machine is required, and 10 rods can be put into the mill in about 1 min. The rod mill is stopped momentarily.

At **Chile Exploration Co.** rods are brought in by railroad flat car and spotted beneath a monorail, which carries an electric hoist with overhead cab control and has two 16x24-in. rod-handling magnets. The monorail extends over the rod storage bins and the rod charging car. One man operates the hoist and another guides the rods to keep them parallel. Three 700-ton storage bins inside the concentrator and additional bins outside are served by the same monorail system.

Rods are charged by a battery-propelled machine, Fig. 6, traveling on 84-in. gage rails behind the mills. They are dropped one at a time on a spinning roll which thrusts them into the mills; a telescopic extension prevents their dropping on the discharge trunnion. Only two men are necessary at the charging machine, but five are needed to operate the heavy plug doors, which are opened and shut while the mills are running. Mills are shut down for about 3 min every other day to charge 15 to 18 rods. A printomatic track scale is available to weigh charges.

Balls are received in steel drums and dumped from these into one of six 400-ton storage pits. A floor-controlled electric hoist with a magnet of 45-in. diam is suspended from a monorail running over the pits and the car charging hopper. The magnet delivers the balls from the pits to the hopper, which discharges through a gate into a ball charging car. This car, of 2-ton capacity, is driven by a small battery locomotive on a 24-in. gage track in front of the mills. At each mill a chute delivers balls to the drum feeder through the feed launder. The car has a gate and a hopper bottom which delivers balls to the chute. One man working part time weighs the charge on a printomatic track scale. By means of a gate on each mill chute, a charge for two days is placed the same day.

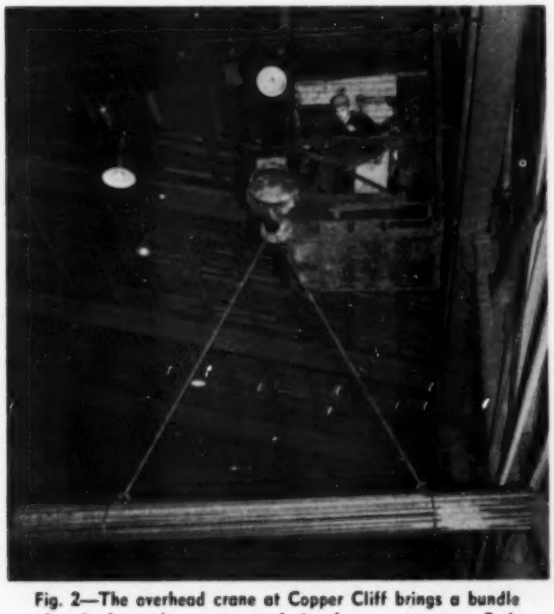

Fig. 2—The overhead crane at Copper Cliff brings a bundle of rods from the empty stock in the concentrator. Rods weigh four to a ton.

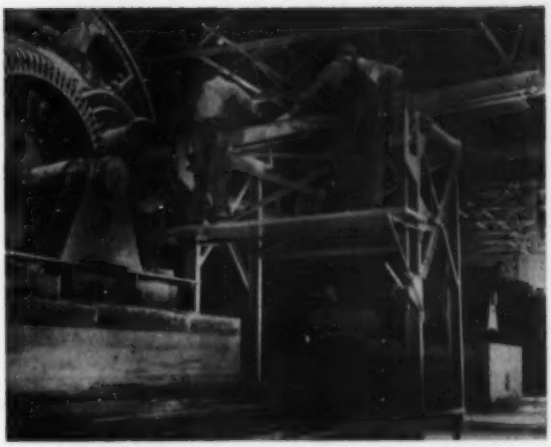

Fig. 3—The above rodding device at the Federal mill, St. Joseph Lead Co., is a modified version of the one used by International Nickel Co. in Canada.

When a similar method is used to charge the regrind mills, balls fed through the drum feeder are thrown out by the scoop. Because of this fault in scoop design, regrind mills are loaded through the shell doors about twice a month. Balls are fed to the mills by a gate-controlled hopper suspended from a crane hook. One and a half hours are necessary for each charge.

At **Cananea Consolidated Copper Co.** balls for the eight 10x10-ft Marcy ball mills are received in railroad box cars, 60 tons to the car. At the unloading point the railroad track is above the general yard level and the balls are rolled and pushed from the cars into a chute leading to a 10-ton end-dump truck, which delivers to the concentrator ball bins 0.6 miles distant.

Walls of the 350-ton capacity concrete bins are 1 ft thick and floor slabs 2½ ft thick. Suspended from a trolley on a 10-in. I-beam is a Yale Cable King hoist of 2-ton capacity. The hoist carries a 39-in. high intensity lifting magnet using 230 v dc. The trolley is operated by a dc motor of 7½ hp. A load of balls picked up by the magnet from any one of the four bins is dropped into a hopper, which discharges into a box or car body mounted on a trailer hauled by an electric motor, both running on a 24-in. gage track. The track is supported on a concrete shelf which is part of the common wall of the concentrator and the fine ore bin.

The trailer truck of the special electric wheel tractor, Fig. 7, has a simple pin coupling on each end to connect it with a similar coupling on the other end of the tractor. The box holding the balls, which is mounted on the trailer, is constructed of ⅜-in. plate with angle reinforcement at the corners around the top. On the track there is a dial scale of 5000-kg capacity, equipped with a printing device.

At each of the eight grinding sections balls are delivered from the car to the feeder drum of the mill by a steel chute, which is lined with discarded conveyor belting to decrease wear and eliminate

Fig. 4—The rod charging machine shown above, Union Miniere du Haut Katanga, is equipped with swiveling castors to position it for use or for storage.

noise. It is flared at the upper end and extends under a lip at the gate of the ball box on the trailer truck. The chute is 8 ft 8¾ in. long and 18 in. deep, narrowing from 2 ft to 15 in. wide and sloping at 3½ in. per ft.

At the end of this launder there is a downspout 7 ft 3 in. long and 12x15 in. on the inside. The bottom is made of ½-in. plate. Should there be a choke, which seldom occurs, one side of this spout is removable. From the side and at the bottom of the downspout a launder 15 in. long, 12 in. wide, and 10½ in. deep, with a slope of 2½ in. per ft, delivers the charge to a box which receives the ore feed for the section. The box discharges down the feeder spout into the feeder drum of the mill. To prevent possible choking, the ore feed is stopped for the few minutes necessary to charge the balls.

If possible the daily charge, which is governed by the operating time of each mill, is a little less the actual wear rather than more. From past experience, 900 kilos is considered the charge necessary for a 10x10-ft Marcy mill in a 24-hr day. When a mill has run 24 hr the preceding day, as is usual, it receives 900 kilos. If the time is less, the charge is adjusted accordingly. If on occasional inspection the superintendent considers the ball level too high or too low, extra charges are put on the daily sheet or the regular charge is omitted. Often an entire month passes without any of these adjustments. Ball levels are maintained 6 to 8 in. below the center line of the mill.

In the supply department ball stocks are carried by bins as well as by order numbers. When a bin is empty a cutoff is made and any shortage paid for immediately. If there is an average it is absorbed by current operations.

Since one man can charge the balls in less than 3 hr, a daily average of 3 hr should take care of the regular charges and any extras. Unloading a 60-ton car into a truck requires the labor of the truck driver and three men for 4 hr.

Guy H. Ruggles, who describes these operations at Cananea, considers this the best ball charging system he has ever seen, except that he prefers delivery to bins by railroad cars rather than by truck haulage. The system was designed in the New York office of Anaconda Copper Mining Co.

In addition to the eight Marcy mills at Cananea there are three Allis-Chalmers trunnion discharge mills, 6½x12 ft, for regrinding concentrates. These are charged with 1-in. diam balls plus the scrap which passes the grates of the Marcy mills and is caught in the discharge boxes and launders. Balls are unloaded from the box cars at the same location, whatever the size, but the 1-in. balls are carried by wheelbarrow from the cars to the loading chute. A crew of three men and the truck driver can unload a car in about 12 hr. The truck dumps the small balls into a low wooden pen on the floor. They are then transferred to one of three wooden bins by a 39-in. magnet suspended from the 10-ton crane that serves the regrind mills. A reelite on the crane handles the power cable to the magnet.

For charging the regrind mills there is a steel box 4 ft square, 4 ft 4 in. deep at the front side and 3 ft 3 in. deep at the back, with a spout and a lever gate in front and angle iron legs. After the balls are put into this box by the magnet it is placed in front of the mill, with the spout, which is 13 in. wide, projecting into the combination feeder of the mill scoop. The box is hoppered both ways toward the gate, and with some assistance the balls flow into the feeder when the gate is opened.

Charging is regulated according to the ammeter reading of the 300-hp 2300-v motors. If the ammeter reading is higher than 42, which has proved the most satisfactory, the balls are thrown out of the mill and into the sand wheel on the mill discharge.

About once a week two men working on the floor and one in the crane charge all regrind mills in 3 hr.

E. G. Lewis of **Phelps Dodge Corp.** writes that mills at the Ajo, Ariz., plant are replenished through the discharge heads:

"Grinding balls are delivered to the mill by rail in gondola cars. The cars are switched into the mill building where storage bins are located on both

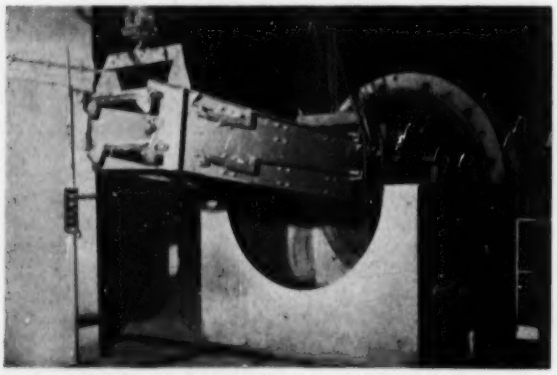

Fig. 5—This rod charger, Oliver Iron Mining Co., is suspended by cable from a monorail.

Fig. 6—The battery-propelled rod charging machine at Chile Exploration Co. travels behind the mills on 84-in. gage rails.

sides of the track. The balls are unloaded from the cars with an overhead crane and electric magnet, two men being required for this operation, [a] craneman and a man on the magnet switch. The two storage bins are divided into three compartments each for segregation of sizes. A gate is provided at the bottom of each compartment for drawing balls from the bins. These gates are operated by rack and pinion.

"Steel boats [Fig. 8] carried by an overhead crane are used in balling the mills. The boats have a capacity of 5000 pounds and have a swinging gate and spout at one end for discharging the balls into the mills. In the ball charging operation the loaded boat suspended from the crane is anchored to the floor by means of a chain attached beneath the spout, which rests on the mill discharge box. A short portable steel launder is used as a runway for the balls from the boat spout to the opening in the center of the discharge head of the mill. This opening has a widening taper into the mill. As the boat is unloaded the rear end is gradually raised by the crane to allow easy flow of the balls from the boat.

"The balling crew consists of four men including the craneman. One man loads the boats from the storage bins while the other two charge the mills. The average time cycle for balling each mill is fifteen minutes. Balls are put into the mills while they are in operation."

At **Climax Molybdenum Co.**, according to Frank Coolbaugh, Resident Manager, two separate methods are used to unload and store the balls. Consistently accurate results have been obtained for a number of years. Figs. 9 and 10 illustrate the handling methods used for No. 2 mill and for No. 3 and 4 mills.

In the No. 2 mill, comprised of eight mill, classifier, and flotation units, balls are stored in heavy wooden bins located between the ore bins and outside the milling section. Because the bins are not situated advantageously with respect to the railroad, balls are unloaded by trucks, discharged into hoppers on high ground above the bins, and fed by gravity to the bins through open launders. One man transfers the correct number of balls every day from the bins to individual hoppers near each scoop box. Balls run by gravity from bins to hoppers through 4-in. standard pipe.

Because the number of bins permits storing a wide range of ball sizes, efficient mixing and testing are possible. Each bin can be piped to feed one to four mill hoppers (not shown in Fig. 9).

"In the new No. 3 and 4 mills with a total of six units," writes Mr. Coolbaugh, "ball storage has been provided inside the mill building in one large divided concrete bin with a capacity of approximately 1500 tons of balls for six different sizes and makes. An overhead crane with magnet quickly unloads from railroad gondola cars or trucks into the storage bins. This magnet also charges the balls to be fed into a transfer bucket for each individual mill. The transfer bucket is picked up by the large mill crane and discharged into ball hoppers located close to the inspection door on the scoop boxes."

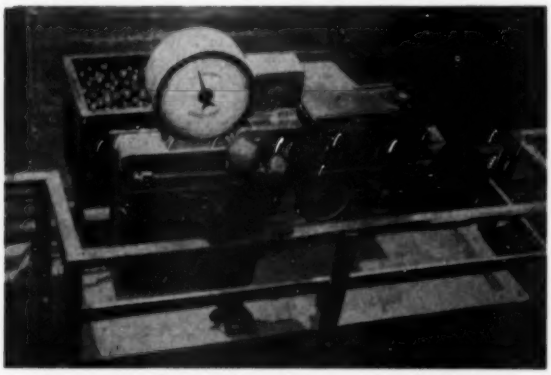

Fig. 7—The electric-wheel tractor with trailer truck, Cananea Consolidated Copper Co.

Fig. 8—Steel boat used in balling mills at the Phelps Dodge concentrator at Ajo, Ariz.

One man handles unloading into storage bins, charging from bins to hopper and from hopper to transfer bucket, and unloading into individual hoppers next to the mills. He is assisted by the crane operator when the transfer bucket is moved from one mill to the next.

In all mills the balls are dropped one at a time directly into the scoops while the mill is running. Day-shift operators can fit this duty into their schedules whenever it is most convenient.

At **Anaconda Copper Mining Co.** modernization plans are not yet completed. In the meantime an overhead crane is being used to lift grinding rods from warehouse stock to the structural steel carriage, which is mounted on wheels and moved by overhead crane. The carriage and the rods are placed directly in front of the 9x12-ft rod mills, and by means of a ratchet and lever, individual rods are placed on live rolls driven by a motor and V-belts. The action of the live rolls throws the rods through the large opening of the Marcy rod mill directly on top of the rod charge.

Small balls are used in the secondary ball mills which operate on a discharge from the rod mills. These balls are loaded in steel containers, elevated by traveling crane, and dumped as required into the ball mill feeders.

As reported by C. G. McLachlan, rod handling at **Quemont Mining Corp.** presents little difficulty, since only one Marcy rod mill, 9 ft 5 in. by 12 ft, is

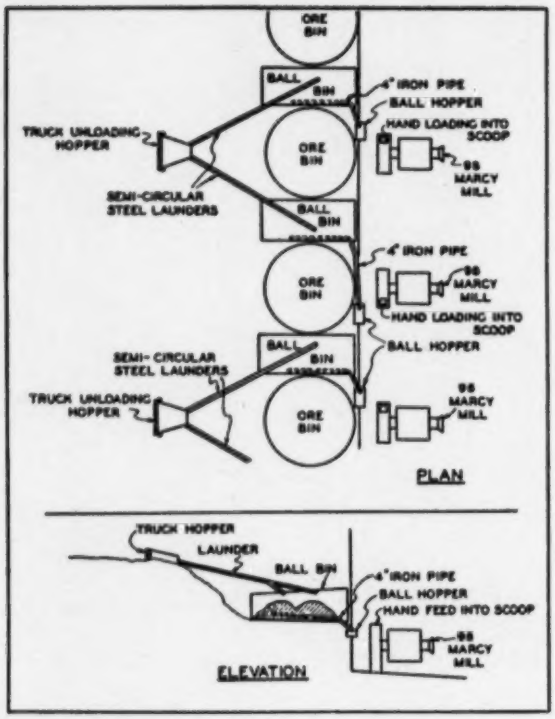

Fig. 9—Elevation and plan of No. 2 ball mill at Climax Molybdenum Co.

operated. The mill is charged with rods 11 ft 8 in. long, of 3½ in. diam, weighing about 390 lb each. Strapped together in units of ten, these are brought in by rail to the Quemont siding, transferred by crane to a truck, and unloaded by crane at the main stockpile, which is located outside the concentrator building near the rod mill grinding bay. There is a smaller stockpile on the ground floor inside the building, approximately 10 ft below the rod mill work floor. Rods are moved from the ground floor to portable racks on the work floor by a 20-ton rod mill service crane.

Twice weekly the mill is loaded with 18 to 21 rods, charged manually one at a time from a portable set of rollers mounted on a light "A" frame and inserted into the discharge trunnion. Seven men working approximately 20 min are required to charge the mill. Total *down* time due to rod loading is about 40 min per week.

At **Quemont Mining Corp.** all grinding balls are delivered by truck to the concentrator and dumped into bins through loading chutes outside the building. Each of the three bins, of laminated wood construction, holds 60 to 70 tons of balls. The bins discharge through small chutes which may be raised or lowered to control the flow of grinding media.

Each of the five 9x12 ball mills is charged daily, three with 2-in. steel and two with 1½-in. steel. The 5 tons of grinding media are charged in 1 hr by a crane operator and assistant.

A 15-ton crane services the mills, which are installed parallel to each other. A loading bucket of about 1-ton capacity, Fig. 11, is lowered to the discharge chute of the appropriate bin and filled. The bucket is then carried to the discharge end of a ball mill and lowered until its spout meets the cut-away section of a 10-in. pipe, which delivers balls into the mill. All mills are fitted with reverse spiral discharge trunnion liners to facilitate moving the steel into the mills.

At the **Phelps Dodge** plant at Morenci a 3-months' supply of grinding balls is kept on hand, since Morenci is far from ball manufacturing centers and would be seriously affected by a steel strike or a railroad strike. There are three storage areas, a large primary storage bin outside the southwest corner of the concentrator building and two smaller rationing bins at each end of the building. The primary bin, of reinforced concrete 18 in. thick, has four compartments partitioned by walls of the same material and thickness. The inside walls are covered with used conveyor belting to prevent chipping and cracking of the concrete when loads are dropped into the bins. Total capacity of the primary bin is well over 3000 tons.

The two rationing bins are located above the loading points for the ball cars. One is divided into four compartments, each with a capacity of 120 tons, and the other into three compartments, each with a capacity of 130 tons. Incoming carloads are diverted to the rationing bins whenever possible; however, if they arrive too close together the balls are unloaded at the main storage bin and transferred as needed.

Balls are transferred from the cars to the main storage bin by a moto-crane with an electro-magnet capable of swinging a ton of balls per load. Unloading time varies from 1 to 1½ hr, depending on conditions existing at the point where the car is spotted. The time is about the same for reloading a flat car when the rationing bins are replenished from the main storage bin. Cars at the overhead bins are

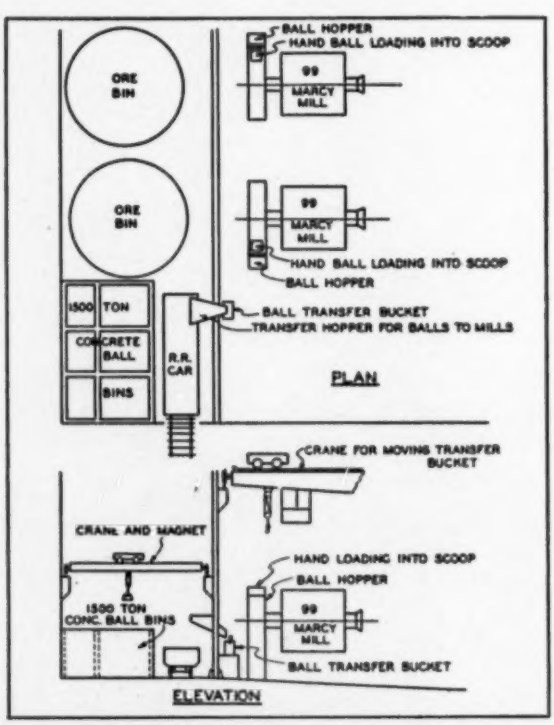

Fig. 10—Elevation and plan of No. 3 and 4 ball mills at Climax Molybdenum Co.

unloaded by a magnet on a traveling crane in the mill itself, the time required averaging 2 hr.

A 24-in. gage railroad runs from one end of the concentrator to the other, passing the mill scoop boxes. Balls are discharged from the overhead bins by gravity flow over a counterbalanced gate spout to a trailer drawn by a battery-operated locomotive. The trailer is drawn over a scale where the load is weighed and recorded. There are two locomotives, each operated by one man. A third man weighs the load, records the weight, and specifies the weights desired for each mill.

When balls are transferred from the cars to the mills, the trailer is spotted between the central point of the mill scoop housing and the sand discharge end of the classifier. The sliding gate on the side of the trailer is opened and the balls roll out over a short guide spout and through a rubber-lined chute to the specially designed drum feeder section of the grinding mill scoop, which takes them into the mill. Charging 28 mills with a ton of balls each requires about 2 hr. The quantity rationed to each mill is determined according to a daily consumption rate adjusted periodically after inspection of the height of ball load. Ball loads are kept to within 4 in. above or below the center line.

Smaller operations are carried out by the **Idarado Mining Co.** of Ouray and Telluride, Colo. Incoming shipments of balls are hauled from the railhead by standard dump trucks to rectangular log cribs built on the ground. New balls, added each shift to compensate for wear, are transported from cribs to a small storage bin near the ball mills as needed. This is accomplished by operating personnel whenever time is available. Balls are carried on the ore feed belt to the mill equipped with a combination feeder. They are dropped into the rotating scoop of the mill equipped with a conventional feeder, having been carried by electric hoist to the top of the scoop box in a steel bucket of 500-lb capacity. This is also done by operating personnel.

When a ball mill is to be relined the full charge of 30,000 lb is dumped on the floor underneath the mill. Three or four men then load it into the specially designed bucket (2000-lb capacity) of a Krane-Kar equipped with a swinging and hoisting boom. The bucket is hoisted to rest on a hopper placed in the manhole and the balls are dumped through the drop bottom. Reloading time is 2 hr.

Procedure is similar at the Telluride mill, except that the bucket for loading balls back in the mill is patterned after the drag-line type. An electric Anaconda hoist is equipped with a Sullivan tugger which holds the bucket away from the mill while a load of balls is being hoisted. When the bucket is in the dumping position the tugger is slacked off, allowing the front end to drop.

The ball bucket, 40 in. long, is 24 in. wide and 18 in. deep in back and 12 in. wide and 9 in. deep in front. It is manually loaded with shovels by four men working in two-man shifts. Shifts are rotated after each man has mucked two buckets, enabling the men to work at top speed. Reloading time ranges from 1 hr to 1 hr 35 min.

At **Waite Amulet Mines Ltd.**, Noranda, Quebec, grinding rods are charged manually to a 9x11½-ft mill. Clearance between the trommel screen of the mill and the wall of the mill building is 4 in. more than the length of the rod used, but the axis of the mill passes through the center of one of the two 5-ft servicing doors, which is opened when the rods are

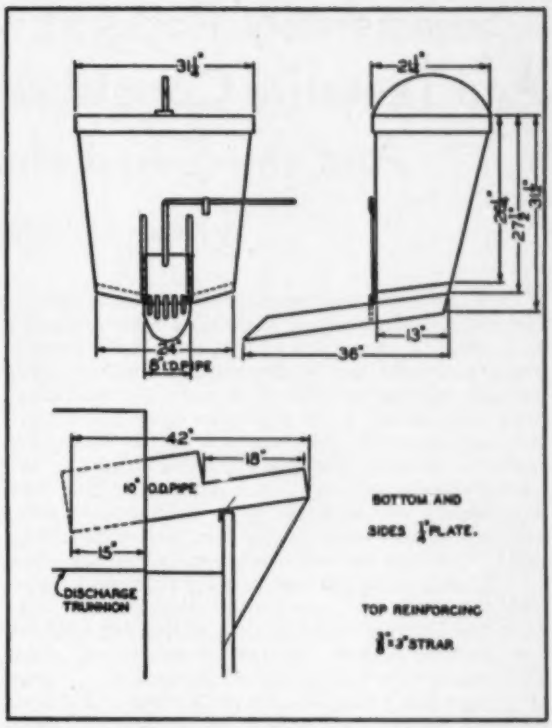

Fig. 11—Ball charging equipment used at Quemont Mining Corp. Bucket spout and loading pipe slope 2 in. per ft.

charged once a week. A surface gang of six men with foreman charges 30 rods in about 20 min, using the following procedure: 1—A roller is placed at the discharge end of the mill, and a saw horse on the floor 7 ft from the roller. 2—Two men rest a half pipe on the roller and the saw horse, while four men place a rod in the pipe, the outer end at stop *a* and the other end extending into the mill. 3—The two men handling the half pipe raise its outer end and, after the saw horse is removed, lower the pipe slightly and push it into the mill until stop *b* reaches the roller. The pipe is rotated through 180° to discharge the rod. It is then withdrawn and the procedure outlined in step 2 is repeated.

Stops *a* and *b* are located to spot the rod correctly in the mill. Prior to their use there was a tendency to push some rods into the feed screw or to leave them in the discharge opening. It is not difficult to drive a rod from the discharge opening into the mill, but there is considerable delay when rods are placed upon others which have been pushed into the feed trunnion.

Conclusion

By means of mechanical operation, large tonnage plants have solved much of the problem of loading, but despite the known benefits of reducing time losses many plants find it difficult to justify the expenditure required to improve methods. The economies of each method of operation should be evaluated carefully.

Acknowledgment

The author wishes to thank the men, and their companies, who so kindly supplied the information on what is necessary to keep the long line of rod and ball mills grinding at top efficiency.

Sedimentary Rocks at Cananea, Sonora, Mexico, And Tentative Correlation with the Sections at Bisbee And the Swisshelm Mountains, Arizona

by Roland B. Mulchay and J. Ruben Velasco

CANANEA has long been recognized as a remarkable field for geologic study. The copper deposits and rocks of the district have been described by many geologists and engineers, but only the most general correlations have been made between Cananea sedimentary rocks and other known sedimentary sections in the southwestern United States and northern Mexico. The present paper describes the Cananea sediments in greater detail than has been done before and attempts to fit the Cananea sedimentary section more closely into the geologic time table. The lack of well-preserved fossils has made it difficult to date the sediments accurately in geologic time, but it is possible to make tentative correlations between the Cananea sediments and the southeastern Arizona sections, based largely upon lithology and general position in the geologic column. It appears that sedimentation at Cananea and Bisbee may have been closely similar during Paleozoic time. Even such generalized correlations, however, may be subject to considerable modification in the future. The present study has led to the recognition of other problems of age and mineralization relationships in the Cananea district.

Cananea is located in the north-central part of the state of Sonora, Mexico, at an elevation of 5270 ft. It is about 135 miles northeast of Hermosillo, the state capital, and 25 miles south of the international boundary. By road Cananea is 40 miles from the twin towns of Naco, Ariz., and Naco, Sonora, and about 50 miles from Bisbee, Ariz. It is served by the Nogales-Naco branch of the railroad, F.C. Pacifico, and is connected with Chihuahua and Mexico City by the Aeronaves airline.

The headwaters of three rivers flowing to the Gulf of California are located in the Cananea Mountains: the San Pedro River, flowing to the north; the Sonora River, flowing south and west; and the Magdalena River, flowing west. Elenita Mountain, the highest point in the district, has an elevation of 8140 ft. The Cananea Mountains extend in a series of north-south to northwest-southeast spurs and ridges and are surrounded by gently sloping gravel plains. The mineralized area, lying across the southern and central parts of the range, is about 6 miles long and at most 2 miles wide. Elevations at the mines vary from 5300 ft at Cananea-Duluth mine at the southeast end of the district to between 6000 and 7000 ft at the west end of the mineralized area at Puertecitos-Elenita mines. Principal production has been from the intensely mineralized and altered area of Capote Basin in the central part of the district and the immediately surrounding area to the southeast. The district has produced over 2 billion lb of copper, substantial molybdenum, and minor amounts of lead, zinc, silver, and gold. Total production through 1949 is estimated at more than $300 million.

In 1900 large-scale development was started at Cananea by W. C. Greene. Until World War II only high-grade ores were exploited; low-grade ores were extracted after the installation of a large concentrator in the early 1940's, and subsequent operations have been based upon mining and processing ores containing less than 1.0 pct copper from open-pit and underground workings. Mining and concentration of such low-grade ores, however, are made possible only by continued high copper prices, and active exploration for high-grade orebodies has been continued throughout the important mineralized areas.

General Geology

Study of the involved rock pattern at Cananea has indicated a complex geologic history for the district. Widespread alteration and mineralization have masked many of the salient features and have led to widely varying geologic interpretations over the years. Further work will probably disclose new information which will modify current beliefs.

At Cananea a conformable series of sediments of probable Paleozoic age was deposited on an unknown basement. Following Paleozoic time there was an extended period of erosion common to many districts in the southwestern U. S., and there is no present evidence of marine sedimentation at Cananea after the Paleozoic. The eroded surface was eventually covered with a great thickness of extrusive volcanic rocks. The entire series of sediments and volcanic rocks was later intruded by a variety of deep-seated igneous rocks. These included the Cananea granite, the Cuitaca granodiorite, the El Torre syenite, the Tinaja diorite, the Campana diabase and gabbro and the Colorada rhyolite quartz porphyry. Faulting of early age, probably prior to the deposition of the volcanic rocks, may have been responsible for the present position of some of the intrusive rock masses. In the Capote mine on the third and fourth levels the northwest-striking Ricketts fault zone, with apparent offset of about 800 ft, has been sealed by a dike-like mass of Cananea granite which gradually increases in size with depth. In lower levels of the mine the granite forms a large southeast-plunging mass generally following the course of the Ricketts zone. The granite is not known southeast of the Capote-Oversight mine areas and the Ricketts fault does not appear in the volcanics southeast of Capote Basin, but several plugs of Colorada quartz porphyry cut the volcanics along the assumed general southeast trend of the Ricketts zone. These porphyritic intrusives may be the up-

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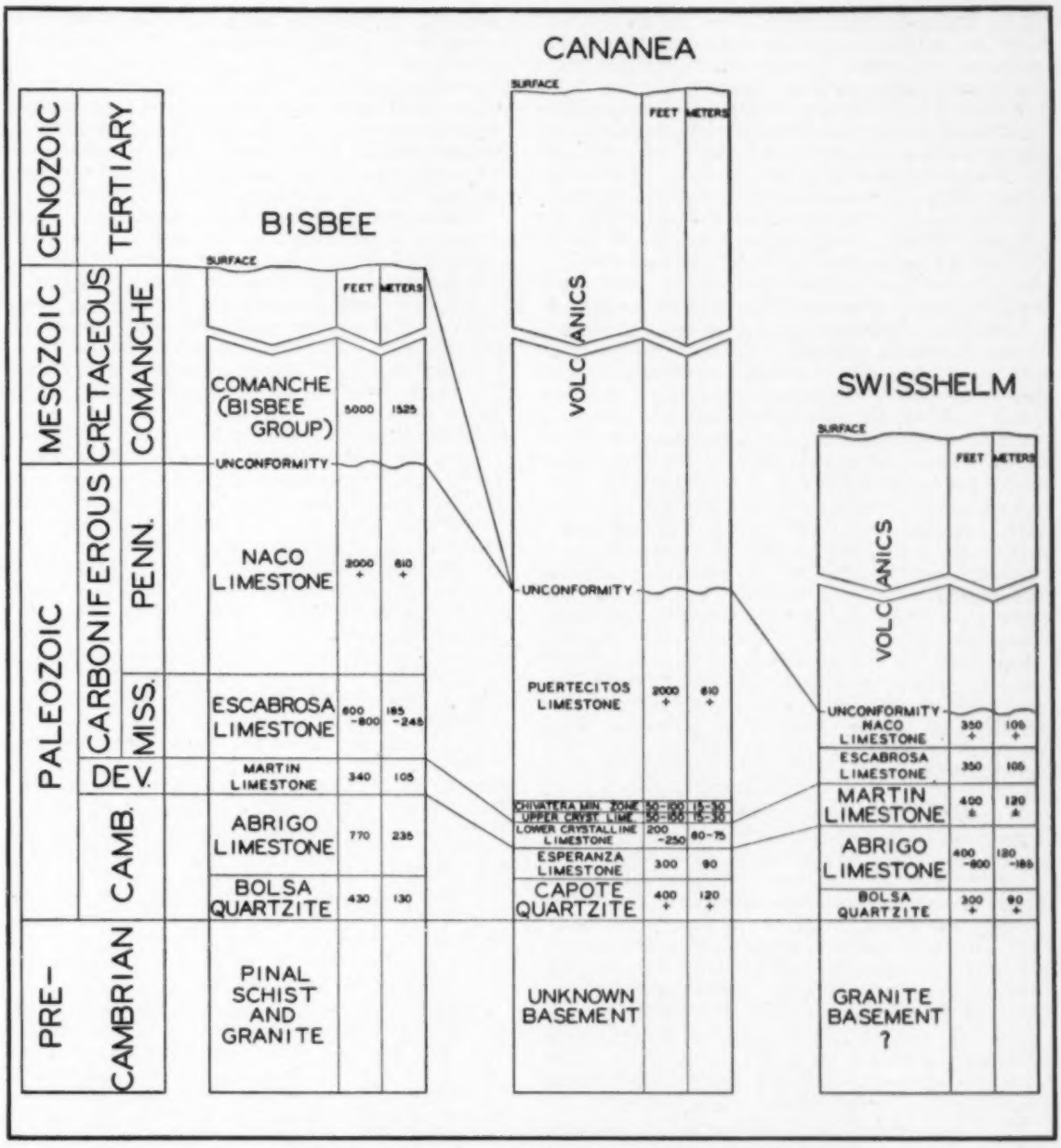

Fig. 1—Comparative stratigraphic columns for Cananea, Bisbee, and the Swisshelm Mountains.

ward expression of a batholithic mass of granite deeply buried beneath the volcanic rocks in the southeast end of the district.

Mineralization occurred in several surges. Sulphide minerals in economic amounts, often locally enriched, were deposited in the sediments, volcanic rocks, and quartz porphyry. Throughout the district upper limestone beds were replaced by garnet. The intimate relations of the garnet and some of the ore minerals suggest that at least part of the widespread garnetization was caused by hydrothermal solutions rather than by limited contact metamorphic effects. Intense sericitization of the volcanic rocks and quartz porphyry was directly related to strong mineralizing activity.

Cananea is lacking in prominent vein structures. Most of the economic mineral deposits are localized in steep-dipping breccia pipes, in disseminated deposits in the volcanic rocks and quartz porphyry, and in replacement deposits in the sediments. Much of the copper ore mined during the past 25 years appears to have been closely related to the quartz porphyry intrusives. After detailed study of the contacts of these intrusives with the volcanic rocks many of the known low-grade ore areas have been enlarged. Mineralized breccia pipes, some of which do not reach surface, have formed feeders for the disseminated minerals in these wide contact zones.

Capote Quartzite: The lowest member of the sedimentary series, and the oldest known rock in the district, is the Capote quartzite. It was formerly believed to have been deposited on the Cananea granite, but underground work at Capote mine has shown that the granite intrudes the quartzite. Composition

of the quartzite in the lowest exposed beds suggests that the sediments were derived from a granitic rock, but the granite and pre-Cambrian Pinal schist basement rocks present at Bisbee below the Bolsa quartzite are not known at Cananea. The quartzite is exposed over considerable areas in Capote Basin at surface and in general has a northwest strike and northeast dip. It is well bedded and is now chiefly composed of quartz and sericite with abundant pyrite. The thickness of the formation is obscured by the intrusive granite and by fault contacts, but a stratigraphic thickness of at least 400 ft is exposed northwest of the Capote mine. Valentine[1] believes there may have been as much as 800 ft of quartzite present.

At Bisbee the lowest member of the sedimentary series, the Bolsa quartzite, is given a thickness of 430 ft by Ransome[2] and is assigned to middle Cambrian age. In the Swisshelm Mountains, some 25 miles north of Douglas, Ariz., the basal quartzite member of the Paleozoic series correlated with the Bolsa is about 300 ft thick and in part at least has been intruded by granite at or near the base.

Esperanza Limestone: Immediately above the Capote quartzite, and with no break in sedimentation, there is a series of very thin-bedded, highly altered, and mineralized limestones. Although these beds have been explored underground for about 3000 ft on strike, no trace of original unaltered limestone has been found. The beds are from 1 to 12 in. thick and are completely replaced along bedding by chlorite, epidote, a little garnet, heavy pyrite, magnetite, hematite, some copper and zinc sulphides, and, locally, gypsum. In particular areas the iron content, chiefly pyrite, is very high, and throughout the series there are small isolated pods and lenses of later chalcopyrite with a little bornite and chalcocite. The upper part of the old and very high-grade Capote orebody, mined during the early days of the camp, is believed to have been a secondarily enriched body of relatively high-grade copper ore deposited in the Esperanza beds. The primary ore minerals appear to have been introduced through the Capote breccia pipe which successively cuts quartzite and granite on the Capote lower levels. Ore within the breccia pipe itself on the lower levels was comparatively low-grade.

The thin-bedded highly altered Esperanza beds are more than 300 ft thick and appear conformable with the Capote quartzite. The upper contact grades gradually into thicker-bedded white limestone.

The Abrigo limestone at Bisbee, which succeeds the Bolsa quartzite in the sedimentary column, was given a thickness of 770 ft by Ransome. The series there is composed of very thin-bedded, shaley, flaggy limestones and is assigned to the middle Cambrian. In the Swisshelm Mountains similar limestones above the basal quartzite member are 400 to 600 ft thick.

Crystalline Limestone: Succeeding the Esperanza beds there is a thickness of 300 to 350 ft of gray-white to dark gray crystalline limestones, locally termed *Crystalline* formation. The darker bands are largely in the lower part of the series. Average analyses of these limestones show they now contain up to 12 pct MgO. The Crystalline beds, which can be traced laterally for over 2000 ft underground, extend at surface as an irregular band, interrupted by faulting, from the Veta mine northwesterly across Capote Basin to the Elisa mine. Beds vary from a few inches to about 3 ft in thickness and are conformable with the remainder of the sedimentary series. The strike is northwest, and dips vary from 25° to 45° to the northeast. Generally there has been little mineralizing activity in the Crystalline beds, but some narrow mineralized bands are parallel to bedding, and a few steep mineralized fissures occur. Locally there is considerable alteration with the development of chlorite and epidote near intrusive igneous rocks.

The only fragmentary fossils discovered to date in Cananea have been found in the Crystalline limestones. In the lower beds poorly preserved and very small spirifers and crinoids, which could not be closely identified, resemble Devonian forms. Somewhat better specimens from the upper beds were discovered in 1925 by G. J. Mitchell[3-4] and were identified by G. H. Girty as Mississippian fauna. The fossils included cup corals and a spirifer of the Rockymontanus group.

Sedimentation appears to have been continuous, passing from the underlying thin-bedded Esperanza limestones, tentatively assigned to Cambrian age on the basis of lithology and position in the section, through the Crystalline limestones and into the succeeding beds above. Taking into consideration the few fossils discovered to date, it appears reasonable to place the lower part of the Crystalline series in the Devonian with the upper beds representing a gradational change into the lower Carboniferous. The thickness of the Devonian might be assumed to be from 200 to 250 ft and the upper 50 to 100 ft of the Crystalline beds included with the lower Mississippian.

At Bisbee sedimentation from the underlying Abrigo limestones to the Mississippian Escabrosa appears to have been continuous, but there is no fossil record of deposition of Ordivician or Silurian sediments. The Devonian Martin limestone, between the Abrigo and Escabrosa, has a thickness of 340 ft as determined by Ransome. The contact with the overlying Escabrosa is not clearly marked and is termed gradational. This is also true in the Swisshelm Mountains where about 400 ft of gray limestones can probably be assigned to the Devonian with gradational upper and lower boundaries.

Chivatera Zone: At the upper boundary of the Crystalline limestones an horizon particularly favorable for mineral deposition contains economic amounts of Cu-Pb-Zn sulphides and has been developed in several mines. The zone, called the Chivatera mineral zone, lies between the massive garnetized horizons of the Puertecitos limestones and the underlying Crystalline series. Locally the mineralized bodies extend into the upper Crystalline beds. The zone has a thickness of 50 to 100 ft and the mineralized lenses fade out on strike. The oreshoots roughly follow bedding on dip, and within the mineralized areas the limestone is entirely altered to chlorite and epidote with irregular chalcopyrite, strong sphalerite, pyrite, a little chalcocite and bornite, and a little calcite and quartz. There is some evidence of mineral zoning with an increase in copper minerals at the expense of sphalerite with depth. The zone is not continuously mineralized, but it has been extensively developed in the Veta 5, Chivatera, Hueco, and Campana mines. The position of this horizon favorable to mineral deposition immediately above the upper Crystalline beds, which contain poorly preserved Mississippian fossils, suggests that it also should be placed in the lower Carboniferous.

At Bisbee the lower Carboniferous Escabrosa limestone has proved a very favorable horizon for replacement deposits. There are many important oreshoots extending from the surface exposures of the original Copper Queen orebody on the west, through the Junction mine and other oreshoots localized around the Sacramento Hill porphyry, to the pipe-like Campbell orebody on the east. These have contributed their major copper content from replacements in the east-dipping Escabrosa beds.

Puertecitos Limestone: Above the Crystalline limestones and the Chivatera zone there is a large thickness of conformable, relatively thick-bedded limestones, almost entirely garnetized. Formerly the entire limestone section at Cananea was known as the Puertecitos limestone, the name having been taken from the Puertecitos area where isolated ore lenses in garnetized limestone were mined in the early days. In this paper the name *Puertecitos limestone* will be reserved for the garnetized beds which are the uppermost beds of the sedimentary series.

Bedding appears to be conformable with the rest of the sediments, although the attitude is much less evident than in the Esperanza and Crystalline divisions. The upper limit of the limestones is an old erosion surface upon which large thicknesses of volcanic rocks have been deposited. Extending east and southeast from Capote Basin the most recent volcanic rocks, the Mesa tuffs and agglomerates, cap the garnetized limestones. Within some mineralized areas the volcanic rocks have also been replaced by extensive garnet masses. The garnetized limestones have a minimum thickness of 1000 ft; below areas capped by the Mesa volcanics the thickness may reach 2000 ft.

The age of these upper limestones cannot be closely determined, but the large thickness which has been changed to almost massive andradite garnet suggests that the entire series was chemically similar. Beds of the Carboniferous Escabrosa and Naco limestones in southeastern Arizona do not differ greatly in chemical composition, and as at Cananea the upper limit of the Paleozoic section is an old erosion surface. On this basis it appears reasonable to assign the garnetized Puertecitos limestone to the Carboniferous and to include the Chivatera zone and the upper Crystalline beds in the Carboniferous without further differentiation.

At Bisbee the Mississippian Escabrosa limestone is 600 to 800 ft thick, and the Pennsylvanian Naco limestones, truncated by an old erosion surface, were measured as 1500 to 2000 ft thick. In the Swisshelm Mountains the Escabrosa was estimated at 350 ft and the Naco, only partly exposed, at more than 350 ft.

On the basis of lithologic similarity and the few available fragmentary fossils found in the Crystalline limestones, the Cananea sedimentary section can be tentatively correlated with the Paleozoic section in southeastern Arizona, see Fig. 1. It must be admitted that there are many sources of doubt as to particular boundaries in the conformable series of sediments, but the general comparisons are reasonable. If further investigation makes possible more accurate dating of the Crystalline limestones, the remainder of the sediments can be placed with greater certainty.

The attempt to date the Cananea limestone section has suggested other problems of considerable geologic interest, such as the ages of the volcanic rocks at Cananea and the following periods of igneous intrusions and mineralizing activity.

Surrounding the Cananea Mountains there are wide, gently sloping mesas of unconsolidated conglomerates which reach a thickness of at least 1100 ft at Del Rio about 8 miles north of Cananea. These gravels cover a pediment of the latest Mesa volcanic rocks which lap onto the lower eastern slopes of the Cananea range. The conglomerates are comparable in age to the Gila conglomerate of Arizona.

To the northeast in the San José Mountains, just south of the international boundary, several thousand feet of folded Cretaceous sediments are exposed which correspond to the Cretaceous beds at Bisbee. Toward Cananea, southwest of the San José range, nearly vertical beds of Cretaceous quartzites and shales are found near the Sauz Arroyo crossing on the Naco-Cananea road. These sediments are succeeded to the south and southeast by volcanic tuffs and agglomerates which can be followed to the southeast into the Ajo Mountains about 15 miles east of Cananea. It is probable that the volcanics at the northern end of the Ajo Mountains can be correlated with the Mesa volcanics at Cananea.

In the Ajo Mountains basal quartzites are reported to rest on pre-Cambrian Pinal schist and to be succeeded by Paleozoic limestones above. Cretaceous limestones are also recognized, although generalized relationships have not been established. Northeast of the Ajos, according to N. L. Taliaferro,[9] there is a considerable thickness of upper Cretaceous sediments with some thin, interbedded ash beds.

Some 25 miles south of the Cananea Mountains, at San Antonio Ranch there are extensive surface exposures of shales of probable Cretaceous age; the area between Cananea and San Antonio is largely covered with volcanic rocks.

The problem of the age of the volcanic rocks at Cananea is an interesting one that cannot be fully resolved at present. The Mesozoic sediments found around the Cananea area apparently were deposited through most of the Cretaceous period. Sediments of this age may have been deposited at Cananea, but none are now in evidence. If present originally, they were stripped by erosion before the volcanic rocks appeared. It seems unlikely that the great thickness of Cananea volcanic rocks could have been formed during a period in which there was nearby sedimentation such as appears to have extended through most of the Cretaceous. On this basis the Cananea volcanic rocks are probably not older than late Cretaceous.

As three thick volcanic series have been recognized, the Elenita, Henrietta and Mesa, all separated by erosional gaps, it appears that volcanic activity must have extended over a considerable time. Intrusion of the deep-seated igneous rocks into the volcanics and the following mineralization may have occurred later in geologic history than has previously been believed.

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Ground Water Control in Underground Mining

by R. C. Mahon

THE importance of ground water control in glacial drift overlying mines is widely recognized. Adequate handling of the problem results in considerable saving in overall pumping costs, as the cost of pumping the larger quantity of water under low heads from surface wells is more than offset by the decrease in the quantity of water to be pumped from the mine under high heads. Eliminating or partly reducing seepage of water through the ledge reduces moisture content of the ore, a factor especially important in iron ore mines, where a reduction of 1 pct in moisture effects a very material saving. An important though indeterminate saving is also brought about by the elimination of water in the working places underground.

The Homer and Wauseca mines of Hanna Coal & Iron Co. at Iron River, Mich., cover 480 acres. When these mines were started it was possible to operate on only one 40-acre tract, as the depth of water over the remainder of the property was too great to permit operation. Although the average depth of the ground water over the area being mined at that time was less than 50 ft it was necessary to pump 1200 gpm from the mine, the greater part from a depth of 750 ft. The slate footwall and graywacke hanging wall are almost impervious, and it was apparent that seepage into the mine was mainly through the iron formation in which the orebodies were located. Analysis of the water in the iron formation showed it to be of the same character as that in the glacial drift, while the water in both walls was heavily mineralized, also indicating that the water passed much more freely through the iron formation.

The first attempt to take off the water above the ledge was by means of drainage drifts driven 15 to 20 ft below the ledge, Fig. 1. Various schemes were used to get the water into these drifts: 1—Holes 15 to 20 ft long were drilled from the back of the drifts to the ledge, but these were difficult to drill and blocked easily. 2—Sections of the drifts were blasted down. This gave a large flow for a time but eventually almost total blockup occurred. 3—Raises 4x4 ft were driven above the drifts to within 8 ft of the

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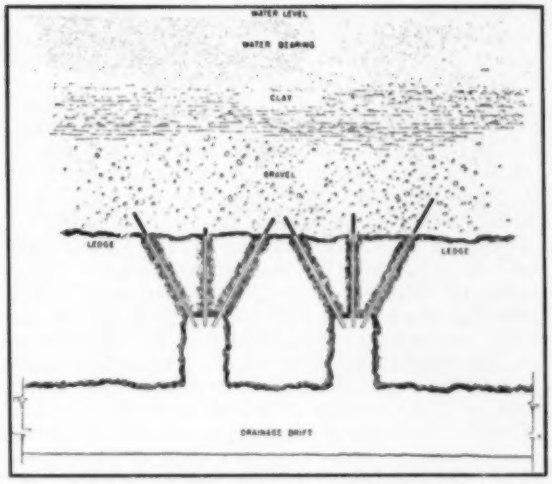

Fig. 1—Theoretical section of the M. A. Hanna Co. Homer mine at Iron River, Mich.

ledge. From these raises holes of 3½-in. diam were drilled to the glacial drift above the ledge and 2-in. pipes perforated at the upper ends were forced up into the glacial drift as far as possible. These holes stayed open for a long time and when blocked could be opened by turning and pounding. By this means 1000 gpm were taken off the ledge. This method did slow the seepage somewhat, but it was evident that it would not solve the problem.

At this time it was determined that a study of the glacial drift was needed, and test holes were put down at strategic points throughout the property, Fig. 2. These holes were drilled with a cable tool Bucyrus Armstrong drill. Eight-inch pipe was used for 100 ft and 6-in. pipe from there to the ledge. In some instances it was necessary to finish the holes using 4-in. pipe. Great care had to be exercised in both the drilling and the sampling. Fine sand formations have a tendency to push up into the casing, and to avoid taking misleading samples it was necessary to slow the pipe and bail it out before advancing. In drilling clay formations the driller had to watch his samples very carefully, as the clay frequently went off with the wash water. All samples were filed for future reference.

These test holes indicated that over a large part of the orebody the water level averaged 150 ft above the ledge. The upper 70 ft was made up mainly of water-bearing sands and gravels. The lower 80 ft was mainly impervious clays with small seams of sand and gravel. From this information it was evident that the water above the clay could not be drained through drifts.

It was then decided to take the ground water off by means of surface wells. The first well was started in June 1929, and by March 1932 five wells were in operation, four of which were sunk only to the clay seam. By now 5000 gpm were being pumped from drainage drifts and surface wells at an average head of 110 ft, and the water pumped from the mine had been reduced from the 1200 gpm in 1929 to 150 gpm. Total pumping costs at that time were 30 pct less than in 1929 because a larger quantity was being pumped from a much lower head. From 1932 to 1936 the mine was idle. Since 1936 eleven wells have been added. Two of the wells sunk to the clay seam have dried up. At present the water level has been lowered to the top of the clay seam, and where the clay is absent average depth of the water above the ledge is now only about 15 ft. The mines are now being operated throughout the 480 acres.

At present 7000 gpm are being pumped from the surface, representing a net gain of about 5500 gpm. Normal rainfall for the district is about 200 gpm per square mile, which would account for a recharge of approximately 800 gpm in the area covered by the mines. Careful measurements have been taken of the rivers and creeks in the area. The normal recharge from the Iron River is approximately 350 gpm, from Sunset Creek 100 gpm, and from the James Mine Creek 100 gpm. During the spring runoff, April to June, this recharge is increased by 500 gpm from the Iron River and 500 gpm from Sunset Creek. There is no evident means of reducing the recharge from the Iron River, but straightening the channels has materially reduced the recharge from both creeks. At present the water level is dropping very slowly, but it is obvious that the drainage gradient is flattening, as a number of wells some dis-

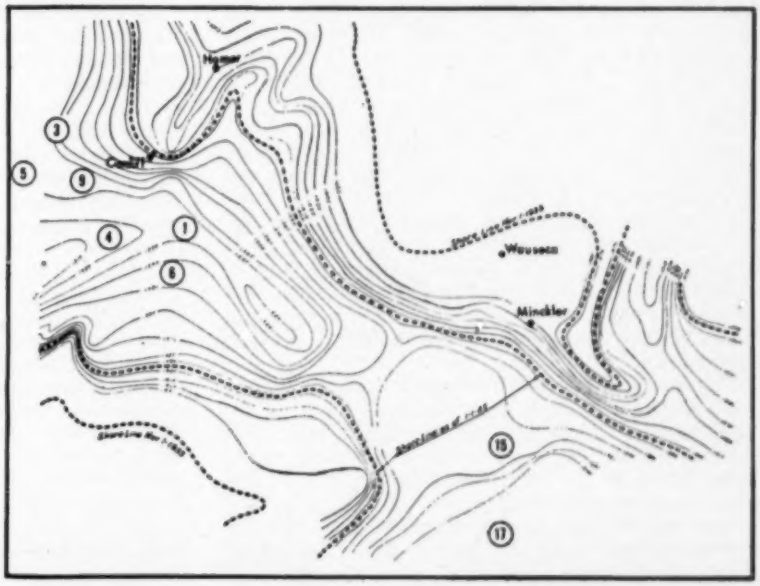

Fig. 2—A ledge contour map of the Homer mine area, Iron River, Mich., showing locations of Homer, Cardiff, Wauseca, and Minckler shafts. Well sites are indicated by circled numbers.

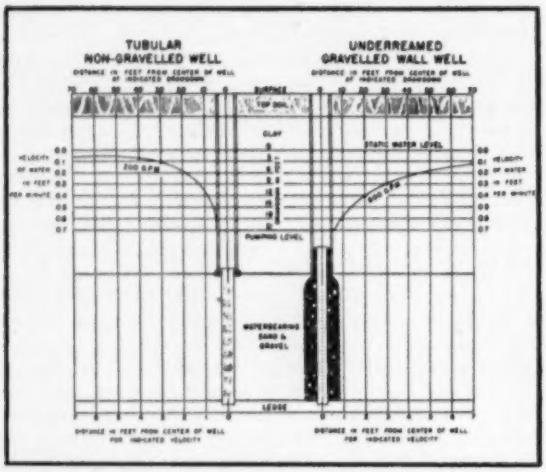

Fig. 3—Superiority of the under-reamed gravel-wall well over the tubular well is shown here. (Reproduced by permission of Layne and Bowler, Inc.)

tance from the drainage area are drying up. It is expected that when the drainage gradient stabilizes there will be a further drop in the water level throughout the area and a reduction in the amount of water to be pumped. Fig. 2 shows the location of all wells, as well as the drop in the water level in 10-year periods.

Before the wells were sunk it was necessary to determine the best drainage areas, the type and size of well, the location and size of screens, and the method of sinking. Samples from the test areas previously mentioned were examined carefully. In general the best drainage areas were found to be those having formations of gravel and coarse sand without clay contamination.

There has been considerable discussion as to the type and size of well best suited for this kind of drainage. It has been argued that in the long run a large number of relatively cheap tubular wells would be less costly than a smaller number of large gravel-wall wells. The superiority of an under-reamed gravel-wall well over the tubular one is shown graphically in Fig. 3, which represents tests made by the research department of Layne and Bowler, Inc. Although the tubular well is originally less costly it has many disadvantages, particularly the fact that 1—high entrance velocity reduces its capacity, and 2—sand cutting destroys the screen in a comparatively short time and cavities form which eventually cause caving and clogging. The gravel-wall well provides a much greater area around the well from which the water is drawn, thereby lowering entrance velocity and increasing the capacity. Sand cutting and caving are eliminated. This type of well will maintain a greater production over a much longer period of time. In this case it was important that the property be drained as soon as possible and it was decided to use the larger gravel-wall wells.

Well size was governed by depth to ledge, extent of drainage area, and expected inflow.

For the first wells the bailing method was used. A cribbed shaft was sunk to the water level and a casing 30 to 36 in. was placed in the shaft. The casing was heavily loaded with sand bags at the surface and sinking was accomplished by bailing out the material inside the casing. When increasing friction on the casing prevented its sinking further a smaller casing was placed inside it and sunk in a similar manner until the ledge was reached. Clearance was allowed between the casings so that gravel could be fed down outside each one.

Greater capacities were achieved for later wells by use of a rotary drilling rig. The rotary drill may be used initially or a cribbed shaft may be sunk to the water level. A 30-in. casing is placed, and the well is completed to the ledge with the rotary drill. Water is forced through a hollow drill stem, and heavy mud carries the cuttings to the surface. The hole is kept open by the water pressure. When necessary *aqua gel* or its equivalent is added to help keep the water in the hole from seeping out too fast. After the hole has been drilled to the ledge a hydraulic under-reamer is used to increase the diameter in the water-bearing formations. This under-reamer is made up of a number of nozzles directed against the sides of the hole. Water is forced through the nozzles at high pressure and as the under-reamer is revolved the diameter of the hole is increased. After the cuttings have been bailed out of the well the casing, with screens located in the correct places, is lowered into the wall and the space between the casing and the sides of the opening is filled with the proper size of gravel. With this method a much better gravel-wall is obtained and the drainage area of the well is increased.

Recently a new method of sinking wells has been introduced, known as the reverse circulation method. A larger drill pipe is employed, usually 7 in. or more in diam, with a drill-bit on the lower end. A high-capacity suction pump is attached to the top of this pipe, with an impeller designed to take very coarse material. This pump lifts the water to the surface, together with cuttings, which are sized up to about the diameter of the drill pipe. The cuttings are allowed to settle and the water is recirculated. If large boulders are encountered, the drill pipe must be taken out and some other method used to remove them. In sandy formations particularly, or where there are few large boulders, this procedure is much faster than the standard rotary-rig method. With this reverse circulation procedure the casing with its screen and gravel-wall is placed in the same manner as that described for the standard rotary-rig method.

All wells are equipped with vertical centrifugal pumps; these are placed at the bottom of the wells and driven by means of a shaft in a tubing, the shaft being connected to a vertical motor at the surface. In general these pumps have efficiencies of more than 80 pct and operate very satisfactorily. Concrete weir boxes have been constructed at each well and weir measurements are taken weekly. In time the efficiency of the pumps is lowered as the water level goes down and the pumping head increases and the quantity of water pumped decreases. Periodically power readings are taken. When it is found that efficiency has dropped to a critical point the pump is raised and either corrected or replaced with a more suitable unit.

Although advances made in ground water control at the Homer and Wauseca mines have been very satisfactory, further study and experimentation are certainly warranted. Improved methods of sinking the wells to reduce both cost and the length of sinking time are in process of development. Experiments should be undertaken to determine the feasibility and economy of using *aqua gel* or clays to seal the beds of streams and lakes. The problem of recharge is of paramount importance in ground water control.

Properties of Nonmagnetic Taconites Affecting Concentration

by Donald W. Scott and Adam L. Wesner

This paper describes the study of 23 nonmagnetic iron-formation samples from the Mesabi Range and shows the significance of their chemical, mineral, and physical properties in terms of their concentration. Data presented here resulted from a research project carried out from 1942 to 1952 by 10 major producers of iron ore, working in conjunction with Battelle Memorial Institute.

THE inevitable depletion of Mesabi direct-shipping iron ores, hastened by recent wars, has increased the importance of developing methods to concentrate iron-formation materials. Many mining companies, independent research organizations, chemical companies, and equipment manufacturers are devoting attention to this important work.

It is only natural that magnetic iron-formation materials have received major emphasis, since magnetic recovery methods apply and reserves of Mesabi magnetic taconites are large. However, the nonmagnetic* iron-formation materials are likewise believed to represent a large reserve and their study has not been neglected.

* There has been a general tendency to use the terms *oxidized taconites* and *nonmagnetic taconites* synonymously. This is not strictly correct. The term *nonmagnetic taconites* is used herein to mean those formation materials that contain appreciable amounts of the iron in oxide minerals other than magnetite.

Beginning in 1942 a joint investigation was carried out by the major producers of iron ore in the Lake Superior region. In this investigation 23 samples from the Mesabi range, 10 samples from the Gogebic range, 10 samples from the Marquette range, and 5 from the Menominee range were studied. This article describes the 23 nonmagnetic iron-formation samples from the Mesabi range, and shows the significance of their chemical, mineral, and physical properties in terms of their concentration.

Although there is lack of accord on the geological mechanism by which Mesabi *high-grade* ores were formed, it is generally agreed that they were enriched in place and that *taconites* are the parent unenriched or possibly unaltered strata. Mining operations over the years have shown that in addition to the unenriched taconite, which is dense and hard, and the direct-shipping ore, there are transition taconites grading into the friable *wash*, or *intermediate* ores. The transition taconites are less massive than the unaltered taconites and usually coarser-grained. This variation, coupled with the fact that there were no extensive drillings in the unaltered taconite, posed a most difficult problem of obtaining samples that would be representative of large tonnages of the fresh rock. The problem was increased by the tremendous extension of the nonmagnetic formation materials on the Mesabi and by the question of their accessibility to mining. A drilling program was evolved that would surmount these difficulties.

Selection of samples was made by a committee representing producers in the area. The samples were procured from 1—taconite walls near bodies of stripping burden or wash ore and 2—from shafts in the process of being sunk through taconite for drainage or mining operations. Most of the samples were obtained from the cherty horizons because it became obvious early in the program that the slaty horizons represented an exceedingly difficult concentration problem, owing to the character of the gangue minerals and the fine grind required for liberation of the valuable minerals. More samples were procured from the lower cherty horizon than from the upper cherty because it was more accessible to mining.

It is not known how well the samples selected represent the nonmagnetic iron-formation material. However, they were chosen by people well acquainted with the geology of the Mesabi range and the mining problems involved. It is believed that they represent a fair cross-section of the types of materials that will be encountered.

Table I gives data on the origin of the 23 samples and the horizon footages from which they were obtained. Samples 1 through 10, and 15 and 16

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(about 1 ton of each) and samples 17 through 19 (20 tons each) were obtained from exposed taconite walls after removal of the obviously weathered material. Samples 11 through 14 (12 tons each) and samples 20 through 23 (25 tons each) were obtained from shaft-sinking operations through previously unexposed taconites. Considering freshness of sample and accessibility to mining, samples 20 through 24 from the Frazer shaft are probably more significant than samples 11 through 14 from the Leonard-Burt shaft, because the former are from the top part of the lower cherty horizon, whereas the latter are from the lower part.

Some of the taconites were a more or less uniform black, red, green, or yellow, and others were banded with light-colored areas of gangue components. Differences in grain size and general structural features were also evident, as shown in Table I. Samples from the slaty horizons were fine-grained and bedding was apparent. Those from the cherty horizons were coarser-grained, although grain size was variable, and more massive, with slight to pronounced banding of alternate gangue and iron minerals in bands up to ¾ in. wide. Samples 8 and 16, in particular sample 8, were coarse-grained and friable, indicative of transition material.

Chemical Composition of Samples

Tables II and III give the respective chemical and magnetic assays. Acid-soluble iron content ranged from 25.3 to 43.4 pct Fe and 17 of the 23 samples assayed 27 to 34 pct Fe. The total iron (acid-insoluble iron also included) was slightly higher in most cases. The ferrous iron content, which occurred in iron silicates, iron carbonates, and magnetite, ranged from 2 to 15.6 pct and seldom exceeded half the total acid-soluble iron content. The ferrous iron content, from 9.9 to 15.6 pct for samples 20 through 24, illustrates the unoxidized character of samples from the Frazer shaft.

The magnetic-iron assays, made on samples ground through 270 mesh, varied from 1.8 to 27.7 pct, accounting for 5 to 85 pct of the total iron. The average for all the samples was 40 pct of the total iron. X-ray and microscopic studies showed that the magnetic concentrates contained some particles that were intimate mixtures of nonmagnetic iron-bearing minerals with enough magnetite to permit recovery in the concentrate by the Davis tube.

The phosphorus content ranged from 0.013 to 0.056 pct. In 17 of the samples the assay was 0.031 pct phosphorus, or less.

Silica, the major gangue constituent in all cases, ranged from 35.1 to 56.1 pct, and from 45 to 52 pct in 18 of the samples. The usual alumina content was of the order of 0.10 to 0.40 pct, exceeding 1 pct for only 5 samples. The carbonate content, representing a major portion of the ignition loss, varied from 0.2 pct to a maximum of 10 pct. The ores with high carbonate content were also high in CaO, MgO, and MnO. The six ores high in CO_2 content were also the highest in Al_2O_3.

Mineral Composition of Samples

Table IV shows the gangue minerals in the taconites and the distribution of iron among the various iron-bearing minerals. Iron-bearing phases included the oxides hematite, magnetite, and limonite, an impure iron carbonate, the mineral minnesotaite, and a limonitic chert. Gangue minerals included quartz, and the silicates greenalite, glauconite, serpentine, stilpnomelane, and clay.

Iron Oxides: Hematite, Magnetite, Limonite, and Goethite; Hematite (Fe_2O_3, 70 pct Fe) and magnetite (Fe_3O_4, 72.4 pct Fe) were usually more abundant than limonite ($Fe_2O_3 \cdot H_2O$, water content variable; 59.8 pct Fe for the formula n = 1.5). The percentage of total iron accounted for in the mineral form of hematite varied from a minimum of 0 to 5 pct for 5 samples to 65 to 80 pct for 7 samples out

Table I. Origin of Mesabi Taconite Samples and Description

Sample	Mine	Horizon* Name	Horizon* Location, Ft	Horizon, Pct	Description
1	Webb	Upper cherty	Upper 80	46	Fine-grained, massive banded taconite
2	Shenango	Lower slaty	Lower 61	61	Very fine-grained, bedded, slaty taconite
3	Shenango	Lower cherty	Top 35	14	Fine-grained, massive, not banded
4	Shenango	Lower cherty	35 to 122 from top	35	Granular and massive, pronounced banding
5	Adams pit	Lower cherty	60 to 100 from bottom	15	Granular and massive, pronounced banding
6	Mountain Iron shaft	Upper cherty Lower slaty	Bottom 24 Top 73	16 44	Fine-grained, bedded, slaty taconite
7	Mountain Iron shaft	Lower slaty	Bottom 97	59	Fine-grained and laminated
8	Danube	Lower cherty	80 to 100 from top	7	Coarse-grained and somewhat friable banded taconite
9	Corsica	Upper cherty	310 to 350 above quartzite	19	Fine-grained and massive, little banding
10	Mahoning	Lower cherty	135 to 145 above quartzite	4	Fine-grained and massive, little banding
11	Leonard-Burt Drain shaft	Lower cherty	Bottom 45 to 56	4	Very fine-grained, laminated, slaty taconite
12	Drain shaft	Lower cherty	Bottom 32 to 45	5	Very fine-grained, laminated, slaty taconite
13	Drain shaft	Lower cherty	Bottom 21 to 32	4	Very fine-grained, laminated, slaty taconite
14	Drain shaft	Lower cherty	Bottom 9 to 21	5	Fine-grained, massive, slightly banded taconite
15	Adams pit	Lower cherty	75 to 100 from top	9	Fine-grained, massive, slightly banded taconite
16	Spruce pit	Lower cherty	150 to 170 from top	7	Medium-grained, somewhat friable transition taconite
17	Adams-Spruce	Lower cherty	5 to 53 from top	17	Fine granular, massive, banded taconite
18	Adams-Spruce	Lower cherty	51 to 92 from top	15	Fine granular, massive, pronounced banding
19	Adams-Spruce	Lower cherty	92 to 124 from top	11	Fine granular, massive, pronounced banding
20	Fraser shaft	Lower slaty† Lower cherty	450 to 490 below surface	37 1	Fine granular, massive, moderate banding
21	Fraser shaft	Lower cherty	490 to 543 below surface	21	Fine granular, very dense, slight banding
22	Fraser shaft	Lower cherty	543 to 577 below surface	14	Fine granular, massive, moderate banding
23	Fraser shaft	Lower cherty	577 to 640 below surface	25	Fine granular, massive, slight banding

* Precise data on the stratigraphy at the sampling points were not available; that used was of the closest reported point shown on the longitudinal section map by John W. Gruner, Minnesota Geological Survey Bull. 19.

† Location tag accompanying sample 20 classified sample as lower cherty; plot indicated that most of sample came from lower slaty. True location questionable.

Table II. Chemical Analysis of Mesabi Taconite Samples

Sample	Total Fe*	Ferrous Fe	Acid-Soluble Fe	Mag. Fe†	Nonmag. Fe†	SiO_2	P	CaO	MgO	Al_2O_3	MnO	Carbonate, CO_2	L.O.I.**
1	32.9	3.0	32.3	11.0	21.3	51.5	0.016	0.01	0.01	0.15	0.24	0.05	1.78
2	25.4	12.8	25.3	5.9	19.4	46.1	0.029	0.34	1.97	2.00	2.18	9.4	9.40
3	27.7	13.1	26.8	5.4	21.4	50.0	0.027	0.01	0.05	0.19	0.74	5.6	7.97
4	33.1	7.4	32.7	19.7	13.0	49.7	0.026	0.03	0.05	0.14	0.52	1.16	1.63
5	34.1	7.6	33.6	17.6	16.2	47.6	0.022	0.02	0.11	0.24	0.49	1.79	1.79
6	32.4	7.7	32.3	18.2	14.1	48.4	0.033	0.15	2.49	0.70	0.18	0.3	0.13
7	32.9	12.8	32.7	27.7	5.0	47.3	0.013	0.03	2.32	0.40	0.14	1.8	0.94
8	36.7	1.8	36.3	1.8	34.5	46.5	0.016	0.22	0.01	0.14	0.08	0.10	0.64
9	44.2	1.8	43.4	8.4	35.0	35.1	0.027	0.08	0.04	0.41	0.10	0.11	1.31
10	34.1	2.8	34.0	12.3	21.7	49.1	0.025	0.23	0.04	0.22	0.04	0.13	1.57
11	30.0	9.4	29.2	16.0	7.1	48.9	0.025	0.34	0.98	1.00	0.72	4.81	5.9
12	28.5	14.4	28.0	11.1	5.4	45.6	0.038	0.55	1.57	1.20	1.16	9.04	9.1
13	27.9	14.7	27.8	5.9	8.8	44.1	0.043	0.50	1.24	1.42	0.97	10.30	11.0
14	28.7	4.8	28.5	9.5	18.5	56.1	0.046	0.01	0.09	1.03	0.08	0.42	1.2
15	31.4	3.6	31.1	4.7	26.0	53.5	0.039	0.01	0.03	0.29	0.11	0.30	1.7
16	36.5	3.2	36.0	3.6	30.4	45.0	0.017	0.01	0.16	0.42	0.52	1.56	2.1
17	34.1	2.9	34.0	11.6	22.4	50.3	0.020	0.01	0.06	0.10	0.21	0.43	1.09
18	33.3	1.5	33.2	6.1	27.1	51.3	0.015	0.01	0.07	0.13	0.06	0.31	1.53
19	32.5	1.9	32.4	12.2	20.2	52.6	0.020	0.01	0.10	0.17	0.12	0.19	1.83
20	33.5	13.3	32.7	25.2	6.5	43.8	0.025	1.04	1.84	0.26	0.80	3.95	3.2
21	28.8	15.6	27.4	17.6	9.8	46.6	0.056	1.07	3.12	0.36	0.44	5.43	4.9
22	29.2	9.9	27.8	18.4	9.4	47.1	0.022	1.52	3.08	0.33	0.37	2.77	2.6
23	26.7	11.9	25.9	11.3	14.6	47.3	0.031	2.17	2.53	0.79	1.17	7.40	7.0

* Determined by fusion. Includes acid-insoluble silicates.
† Magnetic and nonmagnetic assays were determined by Davis-tube tests on 270-mesh head samples. Results reported are calculated as proportional parts of the total acid-soluble iron assays.
** All results for samples dried at 110°C; moisture loss was under 0.5 pct.

of the 23. The distribution of total iron in the mineral form of magnetite varied from as little as 5 to 10 pct for 3 samples to 65 pct or above for 5 samples. There was nothing unusual about the physical and chemical properties of the magnetite and hematite phases occurring in Mesabi taconites, so from a concentration viewpoint the only significance of the distribution described (liberation not considered) is that 5 of the samples, namely, 4, 7, 20, 21, and 22, might be concentrated solely for their magnetite by straight magnetic concentration.

The percentage of the total iron as represented by the mineral limonite ranged from zero for 7 of the samples to a maximum of 20 to 33 pct for 8 of the samples. Generally the hydrated iron oxide was sufficiently crystalline to have the properties of goethite ($Fe_2O_3 \cdot H_2O$ — 62.9 pct Fe), and in this form it might be expected to give no unusual trouble in concentration. In some occurrences, however, the hydrated iron oxide was extremely earthy, probably having coprecipitated with amorphous silica to yield a limonitic chert, the presence of which would be expected to influence the concentration problem.

Minnesotaite:[3] Minnesotaite is a complex iron silicate with a molecular structure similar to talc, except that the major part of the magnesium is replaced by iron. It contains about 28 pct Fe, almost entirely in the ferrous state, 3 to 6 pct MgO, and about 52 pct SiO_2. It is not easy to identify minnesotaite in hand specimens because it resembles earthy chlorite, glauconite, and greenalite, with which it is associated. Of duller greenish-gray color than greenalite, it does not occur in granules but usually is fine-grained and needlelike, with a mottled appearance. Polished surfaces display a bright-green color and a greasy to waxy appearance similar to that of serpentine. It is soft and has 3.0 sp gr.

Under the microscope grains of minnesotaite prove to be acicular, show pronounced anisotropic properties, and appear in sheaflike patterns. When heated to elevated temperatures the material loses its distinct optical properties. The sheaflike pattern persists, but the crystalline structure changes to a semi-translucent, or amorphous-like structure, with a yellow cast almost identical to that of limonitic chert, to be described later.

Minnesotaite accounted for 5 to 15 pct of the total iron in 8 of the 23 samples. On the basis of this distribution and its mineralogy, it is undesirable because the contained iron (30 pct) and silica (50 pct) are chemically combined and cannot be separated from each other by ore-dressing procedures. If the phase is recovered, it will dilute the concentrate with unwanted silica, and if it is sent to waste it will lower the recoverable iron assay in almost direct proportion to the weight percent present, adversely affecting the ratio of concentration and the overall economic picture.

Table III. Magnetic-Tube Tests on Taconite Samples

Sample	Magnetic			Nonmagnetic			Composite Fe, Pct	Feed Assay Fe, Pct
	Weight, Pct	Assay Fe, Pct	Distribution Fe, Pct	Weight, Pct	Assay Fe, Pct	Distribution Fe, Pct		
1	15.7	67.6	34.2	84.3	24.3	65.8	31.1	32.3
2	12.1	47.6	23.2	87.9	21.7	76.8	24.9	25.3
3	8.2	65.5	20.0	91.8	23.5	80.0	26.9	26.8
4	28.4	69.1	60.3	71.6	18.1	39.7	32.6	32.7
5	25.9	67.5	52.1	74.1	21.7	47.9	33.6	33.8
6	28.8	63.4	56.2	71.2	20.0	43.8	32.5	33.3
7	40.2	67.8	84.6	59.8	8.3	15.4	32.2	32.7
8	2.5	71.8	4.9	97.5	35.4	95.1	36.3	36.3
9	12.4	67.5	19.4	87.6	39.6	80.6	43.1	43.4
10	18.1	67.4	36.3	81.9	26.1	63.7	33.6	34.0
11	26.8	62.9	59.8	73.2	15.4	40.2	28.2	29.2
12	21.2	57.4	43.9	78.8	19.7	56.1	27.7	28.0
13	12.1	53.5	24.8	87.9	23.9	75.2	26.6	27.8
14	21.4	59.1	44.6	78.6	20.0	55.4	28.4	28.5
15	2.9	65.8	6.2	97.1	29.2	93.8	30.3	31.1
16	5.3	66.6	9.8	94.7	33.3	90.2	36.0	36.0
17	16.6	67.7	34.1	83.4	26.0	65.9	32.9	34.1
18	8.8	67.2	18.3	91.2	28.9	81.7	32.3	33.2
19	18.0	66.5	37.7	82.0	24.1	62.3	31.7	33.4
20	36.7	70.4	77.2	63.3	12.0	22.8	33.4	33.7
21	26.2	68.8	64.3	73.8	13.6	35.7	28.0	27.4
22	26.6	70.2	66.1	73.4	13.2	33.9	28.3	27.8
23	16.8	69.1	43.6	83.2	18.0	56.4	26.6	25.9

Tests were made on Davis tube magnetic separator. Samples ground through 270 mesh.

It is questionable, however, whether the behavior of the minnesotaite can be easily controlled. Present indications are that it does not respond selectively either to amine or soap flotation procedures. Heat

Table IV. Mineral Composition of Mesabi Taconite Samples

Sample	Distribution of Iron in Iron-Bearing Minerals, Pct					Gangue Minerals
	Hematite	Limonite	Magnetite	Ferruginous Carbonate*	Iron Silicates†	
1	33	33	33			Essentially quartz.
2	25	20	20	25	10	Clay minerals, greenalite, minnesotaite, and stilpnomelane; little quartz.
3	20	25	20	20	10	Greenalite, quartz, minnesotaite, and stilpnomelane.
4	10	20	65	5		Quartz predominates; minnesotaite and greenalite are of lesser importance.
5	25	15	55	5		Essentially quartz.
6	45		50		5	Clay minerals, greenalite, minnesotaite, and stilpnomelane; quartz is minor.
7	5		85	5	5	Quartz predominates; stilpnomelane, minnesotaite, greenalite, and clay minerals are of lesser importance.
8	85	10	5			Chiefly quartz; minor amount of clay minerals.
9	65	15	20			Chiefly quartz; minor amount of clay minerals.
10	35	30	35			Chiefly quartz.
11	15	10**	55	20		About equal amounts of serpentine and quartz.
12	10	<10**	40	40	< 5	Serpentine more prominent than quartz; minor amounts of greenalite and clay.
13	30		20	50	< 5	Quartz predominates; serpentine also present.
14	65	< 5	30	5		Essentially quartz; serpentine very minor.
15	65	20‡	15			Essentially quartz.
16	<80	5‡	10	5	< 5	Essentially quartz; less than 5 pct serpentine.
17	65	15	20	<2		Essentially all quartz.
18	70	20	10	<2		Essentially all quartz.
19	55	20	25	<1		Essentially all quartz.
20			75	20	5	Quartz predominates; minnesotaite, glauconite, and greenalite also present in minor quantities.
21			65	20	15	Quartz predominates; minnesotaite of lesser importance; glauconite and greenalite in minor quantities.
22	5		65	15	15	Quartz predominates; minnesotaite, greenalite, and glauconite of lesser importance.
23	5		45	35	15	Quartz predominates; minnesotaite, and greenalite of lesser importance; glauconite in minor quantities.

* Iron content of ferruginous carbonate varies from 14 to 35 pct Fe, as compared with 48 pct Fe for pure siderite, $FeCO_3$.
† Includes minnesotaite, stilpnomelane, greenalite, and serpentine.
** A portion in the form of limonitic chert.
‡ In the form of limonitic chert assaying 20 pct Fe and 70 pct SiO_2.

treatment of relatively pure pieces of minnesotaite in air, in a nitrogen atmosphere, or in a hydrogen atmosphere, caused a visual change in color and a change in optical properties but did not make the mineral magnetic. Minnesotaite might respond differently when in association with the other minerals of the ore. This remains to be determined. Although indications are that it will not become magnetic, it might be difficult to keep out of a magnetic concentrate because of its intimate association with other phases that are magnetic, or easily made magnetic. This is discussed under liberation.

Limonitic Chert: Hand specimens of the limonitic chert, of a yellowish-brown color, were in structure similar to flint. Under the microscope the chert appeared to be amorphous earthy limonite. Chemical analyses of specimens, which showed only minor crystalline quartz with the microscope at 450X, assayed 20 pct Fe and 65 to 70 pct SiO_2. The intimate dispersion of either submicrocrystalline or amorphous silica with the iron must account for the excess of silica over the quantity of quartz observed. If the free quartz were deleted, the iron and silica assays would be about the same as for minnesotaite, and because the general appearance of limonitic chert is very similar to that of minnesotaite after heat-treating, what has been termed limonitic chert might originally have been minnesotaite, formed from the alteration of that mineral.

The significant point is that it is not possible to separate the SiO_2 from the Fe_2O_3 in the limonitic chert phase by practicable grinding techniques, and as this reduces the recoverable iron assay the chert is an undesirable iron-bearing phase.

The limonitic chert phase was noted in four samples, namely, 11, 12, 15, and 16. It occurred in quantity only in sample 15, accounting for 20 pct of the total iron, so the iron assay theoretically recoverable in high-grade concentrates is about 25 pct.

Impure Siderite or Ferruginous Carbonate: Pure siderite, $FeCO_3$, contains 48.2 pct Fe, but the siderite occurring in the taconites is relatively impure, containing from as little as 14 pct Fe to a maximum of 35 pct, with varying amounts of MgO, CaO, and MnO. Furthermore, most of the impure siderite in taconites occurs in such intimate association with 10 to 20 pct of submicrocrystalline or amorphous silica that it cannot be observed with the petrographic microscope, much less liberated by grinding.

The impure siderite, or ferruginous carbonate, is soft and does not possess the usual resinous luster or the prominent cleavage normally associated with siderite. Rather, it has a dull grayish-black appearance and a slaty structure similar to slaty ores in general. In the hand specimen, it can be easily mistaken for fine-grained taconites composed only of iron oxides and silica.

The ferruginous carbonate was more abundant in taconite than minnesotaite, accounting for 15 to 50 pct of the total iron for 9 of the 23 samples. These were samples 2, 3, 11, 12, 13, 20, 21, 22, and 23. This phase is undesirable for the same reasons given for minnesotaite but is here of more concern because it is more abundant. Its presence in sample 13 actually reduces the theoretical iron recovery in a high-grade concentrate to about 50 pct, or in other words, it reduces the recoverable-iron assay to about 14 pct.

Just how it will respond in the various concentration schemes remains to be established. Evidence at hand indicates that it is extremely toxic to flotation separations, seriously impairing selectivity and increasing reagent consumption. Excessive reagent consumption is peculiar to this impure siderite, since that consumed by high-grade specimen siderite was only one fourth as much.

Siderite must be decomposed to FeO and CO_2 before the iron can be converted to magnetic form. Decomposition proceeds above 840°F. Below this

temperature siderite is unaltered. Thus with temperature conditions in excess of 840°F, it is to be expected that some of the ferruginous carbonate in ore or mixtures of ores containing ferric oxides and ferruginous carbonates will become magnetic. By control of temperature and other conditions, there is some control over the behavior of the ferruginous carbonate, but as in the case of minnesotaite, its intimate association with other phases which would become magnetic should influence its behavior. Thus while impure siderite does not interfere with reduction-magnetic separation procedures to the extent that it interferes with flotation, it is an undesirable iron-bearing component of taconites.

Greenalite, Glauconite, Serpentine, and Stilpnomelane: Glauconite (a hydrous silicate of iron and potassium), greenalite (a hydrated ferrous silicate), serpentine (a magnesium silicate with some iron replacing the magnesium), and stilpnomelane (a complex mixture of bivalent and trivalent silicates containing some iron) may assay up to 20 pct Fe, depending on the degree of hydration. Because the iron in these minerals is chemically combined with silica, they are all undesirable, but because the iron content is relatively low, they can be classed as gangue minerals. Their presence in the taconites was not serious, because collectively they do not account for more than about 5 pct of the total iron in any sample. This was the case for samples 2, 3, 12, 13, 21, 22, and 23. Reduction procedures did not convert them to the magnetic form.

Quartz: Quartz was the most abundant gangue mineral in the taconites. In only two samples, 11 and 12, was it exceeded in quantity by any other single gangue mineral, namely, serpentine. The quartz occurred mostly in crystals in two size ranges: either coarser than 70 microns (200 mesh) or finer than 10 microns (1600 mesh), with only a small amount between these sizes, but quartz grains commonly occurred adjacent to each other to form large quartz areas. On crushing to 150 or 200 mesh, the finely crystalline quartz broke into smaller particles which were aggregates of finer grains, and these aggregates were found to have a hydrous iron oxide coating on the surface which might decrease selectivity in flotation but would not be important either in magnetic or gravity separations.

Mineral Association

To determine the association of gangue and iron minerals, thin sections were studied as well as sized grains from crushing and grinding tests. Dissemination of iron and gangue phases covered the gamut from extremely fine for samples from the slaty horizons to bands of predominantly iron-bearing minerals ½ to ¾ in. wide in some of the samples from the upper part of the lower cherty horizon. Starting points for the liberation of gangue minerals and iron minerals are listed in Table V. Results of heavy-liquid separations for most of the ores are given in Table VI.

In all the samples, with the exception of those containing iron bands, the major gangue mineral, quartz, was liberated at a coarser size than the iron-bearing minerals. Quartz liberation started at sizes from ¼ in. to 35 mesh, depending on the ore. The float-and-sink separations, made on samples crushed 1/4 in., or to 20 mesh, showed that 1/4 to 1/3 by weight was sufficiently liberated to suggest the theoretical possibility of rejecting primary tailings that might assay 10 pct or less of iron and contain about the same percentage of the total iron. Samples 4, 5, 8, 15, 16, 17, 18, and 19 showed the best liberation of gangue at coarse sizes.

The liberation of the iron-bearing minerals, hematite, magnetite, and crystalline limonite, started at a much finer size than the quartz, except for samples 17, 18, and 19, which contained iron oxide bands. These bands were much less abundant than the highly disseminated areas, but reached a thickness of ½ to ¾ in. They graded into disseminated bands and lean bands. The total amount of the iron values in the high-grade bands was small. Although the float-sink data show that a grind of 100 mesh gave good hematite, magnetite, and limonite liberation from gangue on samples 4, 5, 8, and 9, for most of the samples containing essentially a quartz gangue a grind of 150 mesh would be required. Some iron oxide-quartz ores such as samples 10, 15, and 16 will require a grind finer than 200 mesh.

Table V. Liberation* of Mesabi Taconite Samples

Sample	Iron Minerals	Gangue Minerals
1	Starts at 65 mesh	Starts at 10 mesh
2	Requires grind finer than 600 mesh	Starts at 35 mesh
3	Starts at 35 mesh. Liberation of siderite is poor at 150 mesh	Good at 20 mesh
4	Starts at 35 mesh	Starts at 20 mesh
5	Starts at 35 mesh	Starts at 20 mesh
6	Requires grind 325 mesh or finer	Poor at 100 mesh
7	Requires grind 270 mesh or finer	Poor at 100 mesh
8	Starts at ½ in.	Starts at 20 mesh, good at 65 mesh
9	Starts at 20 mesh	Starts at 20 mesh
10	Starts at 65 mesh	Starts at 35 mesh
11	Starts at 65 mesh. Siderite liberation from iron oxides only 20 pct complete in 150 to 200 mesh size	Starts above 8 mesh
12	Starts at 100 mesh. Siderite liberation from iron oxides only 30 pct complete in 150 to 200 mesh size	Starts at 8 mesh
13	Starts at 100 mesh. Siderite liberation from iron oxides only 20 pct complete in 150 to 200 mesh sizes	Starts above 8 mesh
14	Starts about 65 mesh	Starts about 14 mesh
15	Starts about 65 mesh	Starts about 10 mesh
16	Starts about 100 mesh	Starts at 28 mesh
17	Starts about 8 mesh	Starts above ¼ in.
18	Starts about 6 mesh	Starts above ¼ in.
19	Starts about 8 mesh	Starts above ¼ in.
20	Good magnetite liberation at 150 mesh; only 50 pct liberation of siderite	Grinding to 270 mesh improves slightly the liberation of siderite
21	Good magnetite liberation at 150 mesh; poor siderite liberation	At 270 mesh, 50 pct of the siderite is still locked
22	At 150-mesh grind, almost all the magnetite, about 50 pct of the other iron oxides, and 20 pct of the siderite are liberated	Grinding to 270 mesh improves siderite liberation slightly
23	At 150 mesh-grind, almost all the magnetite, 50 pct of the other iron oxides, and 20 pct of the siderite are liberated	Grinding to 270 mesh improves siderite liberation slightly

* A free particle contains 90 pct, or more, of one constituent.

The textural variation in the taconites which consist principally of iron oxides and quartz is illustrated in the photomicrographs of thin sections shown in Fig. 1. The gray areas and the white areas are quartz and the black areas are iron oxides. The coarse-textured taconite illustrated would result in good liberation if ground to substantially coarser than 150 mesh, the medium-textured taconite would result in good liberation if ground to 150 mesh, and the fine-textured taconite would require a grind substantially finer than 150 mesh for liberation.

For Mesabi Range formation materials containing important amounts of the iron in the form of ferruginous carbonate, or minnesotaite, the grind must be much finer. These phases were liberated from the quartz, serpentine, and other gangue phases at sizes ranging from 10 to 35 mesh, but they were so intimately associated with magnetite and hematite that their liberation in the size range 150 to 200 mesh was only 20 to 30 pct complete. Crushing these

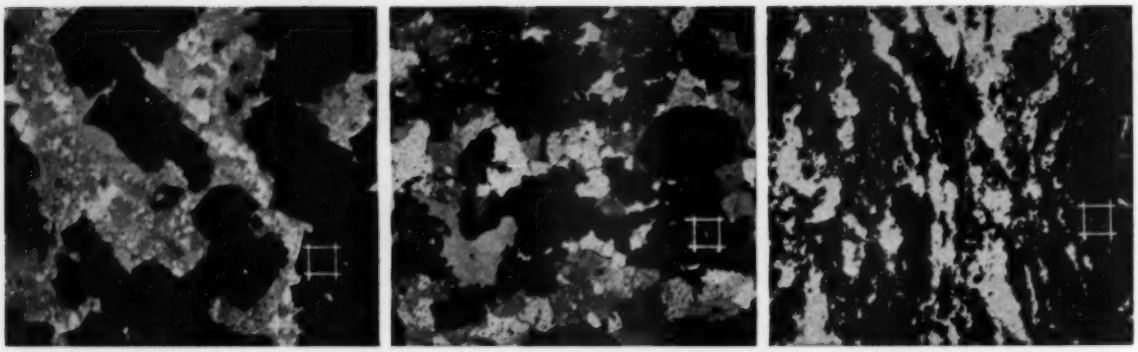

Fig. 1—The above micrographs of thin sections illustrate textural variation in iron oxide-quartz taconites. Gray and white areas are quartz and black areas iron oxide. Left, coarse texture. Center, medium texture. Right, fine texture. Ruled squares indicate a 150-mesh screen aperture.

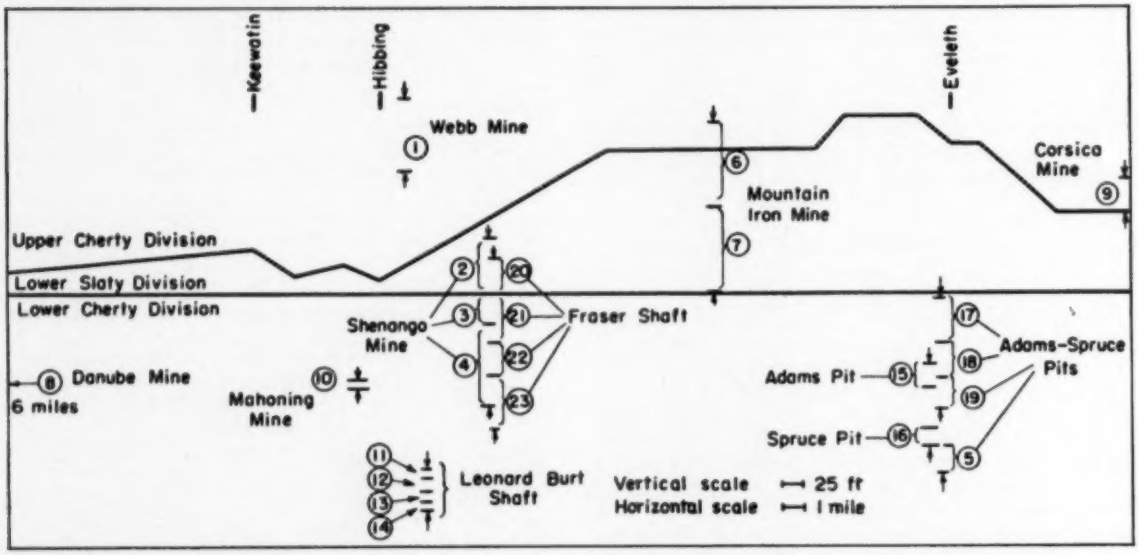

Fig. 2—Approximate stratigraphic and longitudinal location of taconite samples. Horizons located according to longitudinal section map by John W. Gruner.[9]

Table VI. Heavy-Liquid Data on Taconite Samples

Sample	Grind	Product*		Results			
		Sp Gr	Designation	Weight, Pct	Fe, Pct	SiO_2, Pct	Distribution Fe, Pct
14	¼ in.†	Under 2.95	Waste	50.6	14.2		25.3
17	⅛ in.	Under 2.85	Waste	23.9	9.4		6.7
18	¼ in.	Under 2.85	Waste	28.0	10.1		8.5
19	¼ in.	Under 2.85	Waste	22.1	10.6		7.1
1	20 mesh	Under 2.95	Waste	25.6	9.9		8.0
3	20 mesh	Under 2.95	Waste	38.5	10.8		15.9
4	20 mesh	Under 2.95	Waste	37.3	6.4		7.6
5	20 mesh	Under 2.95	Waste	34.5	7.6		7.8
8	20 mesh	Under 2.95	Waste	30.9	4.5		3.8
9	20 mesh	Under 2.95	Waste	17.1	8.0		3.2
10	20 mesh	Under 2.95	Waste	20.9	8.6		5.3
11	20 mesh	Under 2.95	Waste	36.5	14.2		18.0
12	20 mesh	Under 2.95	Waste	36.0	12.0		14.5
13	20 mesh	Under 2.95	Waste	24.7	9.4		5.6
14	20 mesh	Under 2.95	Waste	32.5	11.1		12.7
15	20 mesh	Under 2.95	Waste	22.2	9.2		6.7
16	20 mesh	Under 2.95	Waste	16.7	8.6		4.0
1	100 mesh	Over 3.4	Iron-bearing	46.2	57.0	14.9	86.5
3	100 mesh	Over 3.4	Iron-bearing	38.0	47.3	13.9	68.6
4	100 mesh	Over 3.4	Iron-bearing	46.9	60.9	10.1	91.2
5	100 mesh	Over 3.4	Iron-bearing	51.2	60.3	10.5	91.8
8	100 mesh	Over 3.4	Iron-bearing	55.6	63.0	8.3	97.9
9	100 mesh	Over 3.4	Iron-bearing	64.6	61.0	10.3	92.8
10	100 mesh	Over 3.4	Iron-bearing	48.8	57.8	15.6	88.0
17, 18, 19	2 pct +150 mesh	Over 3.0	Iron-bearing	51.9	60.4		95.5

* Only one product is shown in each case, although two or three were made. In the ¼-in. and 20-mesh separations, the low specific gravity or possible waste products are shown, whereas at 100 mesh the results are given on only the heavy or iron-bearing products.
† On sample 14, the −200 mesh fraction was removed.

samples to −270 mesh improved the liberation of the ferruginous carbonate only slightly. Samples containing ferruginous carbonate which fell in this liberation category were 2, 3, 6, 7, 11, 12, 13, 20, 21, 22, and 23.

The samples studied can be classified in three main groups on the basis of mineral composition and physical association: Group A—Ores which are principally a mixture of iron oxides and quartz with good liberation at 150-mesh grinding. Group B—Ores which contain substantial quantities of iron in the form of impure iron carbonate or iron silicates or require a very fine grind for liberation. Group C—Ores falling between A and B in regard to mineral composition or liberation.

Group A includes samples 1, 4, 5, 8, 9, 10, 14, 17, 18, and 19, all from the cherty horizons. Of these, samples 4 and 5 contain a small amount of siderite and/or minnesotaite and approach the intermediate group C ores. The group A ores present the simplest concentration problem because the iron is present in iron oxides which are high in iron content and become liberated with 150-mesh grinding. Concentrate grades of 60 to 65 pct Fe with iron recoveries in excess of 90 pct are theoretically possible.

Group B includes samples 2 and 6 from the lower slaty horizon and samples 3, 11, 12, 13, and 23 from the lower cherty horizon. The first two are included in this classification mainly because they require a grind through 270 mesh, or finer, for mineral liberation. The others not only require a fine grind but also contain appreciable amounts of impure iron carbonates and/or minnesotaite. With the possible exception of samples 2 and 6, theoretically not over 50 to 60 pct of the iron in these samples could be recovered in high-grade concentrates by ore-dressing methods. Obviously a low recovery of iron would increase the tonnage to be mined per ton of concentrate and would affect economics adversely. Present observations indicate that complex ores of the group B type should not be mined if they can be left.

Group C includes sample 7 from the lower slaty horizon and samples 15, 16, 20, 21, and 22 from the lower cherty horizon. Sample 7 requires a fine grind for mineral liberation. Samples 20, 21, and 22 contain impure iron carbonate and therefore their classification in group C is questionable. However, these four samples contain 65 to 70 pct of the total iron in the form of magnetite, which might offset some of the undesirable factors. Ores 15 and 16 contain a significant amount of iron in the form of limonitic chert, from which it cannot be released, and require for liberation a grind finer than is necessary for group A ores and coarser than is necessary for group B. Consequently all the samples in this group are considered borderline. The samples high in magnetite might be amenable to concentration for this mineral only, whereas the others probably could be handled as diluents of group A ores.

Fig 2 shows the approximate stratigraphic and longitudinal location of the various samples. In conjunction with the sample classification presented, it is apparent that taconites vary widely in mineral composition and texture, both areally and stratigraphically, even within a single horizon. Those from the slaty horizon are too finely disseminated to be favorably considered for concentration. However, Fig. 2 also suggests that within a restricted area the variation might be from simple group A to transition group C ores, or from transition to complex group B ores rather than from simple ores to complex ores.

Further sampling and descriptive mineralogical work are required to determine: 1—the extent to which constituent minerals deleterious to beneficiation techniques are present; 2—the relative importance of stratigraphic variation and of oxidation as factors in determining the complexity of the mineral assemblage; and 3—the local reserves, if any, of group A taconites large enough to justify beneficiation plants.

Conclusion

It is possible at present to draw the following conclusions: 1—Any universal method developed for beneficiation of nonmagnetic taconites must be adaptable to a wide variety of minerals and gangue and iron disseminations. 2—Any satisfactory concentrates produced will be essentially iron oxides plus silica, so that a high iron assay will be required to obtain a reasonable silica assay. 3—High recovery will not be possible on ores containing a high proportion of ferruginous chert, siliceous siderite, or minnesotaite.

Gravity concentration might be used for roughing operations. It offers little promise for finishing operations because of low-unit capacity when ores requiring a fine grind are handled. Flotation holds promise for some ores but a change in mineral assemblage can disrupt the separation. To obtain good selectivity, in some instances the grind must be finer than is necessary for mineral severance. Direct magnetic separation, an operable process, is not generally applicable because the magnetite content is too low. Reduction followed by magnetic separation offers several advantages: 1—iron recoveries are expected to be higher in acceptable concentrate grades; 2—a change in mineral composition will not disrupt the process; and 3—the heat-treated taconites are twice as easy to grind as untreated taconites and the liberation is improved about one screen size because of better boundary fracturing.

Reduction studies have been under way to improve thermal efficiency of the conversion of iron-bearing minerals to magnetic form. Of possible application to the problem are the relatively new reduction procedures recently described in the literature: the fluosolids process,[3] the Royster process,[4] and the reduction-oxidation process.[5]

Acknowledgment

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Correlation Between Principal Parameters Affecting Mechanical Ball Wear

by R. T. Hukki

This paper presents a series of equations for mechanical ball wear, relating parameters of ball size, mill speed, and mill diameter. The fundamental equation, Eq. 12, presented here is introduced to correlate these basic parameters and thus define and clarify the concept of ball wear. This equation is offered as a general rule, which may be modified to apply to individual problems of grinding.

BALL wear as observed in grinding installations is the combined result of mechanical wear and corrosion. Corrosion should be a linear function of the ball surface available. Ball corrosion, however, has been studied so little that its effect, although of great importance, cannot be included in the analyses given here.

In a separate paper[1] it is shown that

$$n = 0.7663\, n_p \frac{1}{\sqrt{D}} \text{ rpm} \qquad [1]$$

$$P = c_1\, n_p\, D^{3.5} \text{ kw} \qquad [2]$$

$$T = c_2\, (n_p)^m\, D^{(3\,-\,m/2)} \text{ tph} \qquad [3]$$

In these equations

n = actual mill speed, rpm
n_p = calculated percentage critical speed
D = ID of mill in feet
P = power required to operate a mill, kw
T = capacity of a mill, tph
c_1 and c_2 = appropriate constants
m = exponent of numerical value of $1 \leqq m \leqq 1.5$

Exponent m is the slope of a straight line on logarithmic paper relating mill speed (on the abscissa) and mill capacity (on the ordinate).

It is generally accepted, although not sharply defined, that ball wear in mills running at low (cascading) speeds is a function of the ball surface available. Accordingly, the wear of a single ball may be considered to be a homogeneous, linear function of its surface and of the distance traveled. Thus

$$dw = f_1(d^2) \cdot f_2(ds) \qquad [4]$$

where dw is the wear of a single ball in time dt, d the diameter of the average ball in ball charge, and ds the distance traveled by the ball in time dt. Indicating that

$$ds = \pi\, D\, n\, dt,$$

the wear of the average ball in time dt becomes

$$dw = f_1(d^2) \cdot f_2(\pi\, D\, n\, dt)$$

$$= f_1(d^2) \cdot f_2\left(\pi\, D\, c_2\, n_p \frac{1}{\sqrt{D}}\, dt\right)$$

$$= c_4\, d^2\, n_p\, D^{0.5}\, dt$$

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The rate of wear of the average ball is given by dw/dt.

$$dw/dt = c_4\, d^2\, n_p\, D^{0.5} \text{ lb per hr} \qquad [5]$$

The weight of the ball charge per unit of mill length is a function of D^2. The number of balls of size d in the ball charge is $= f_3(D^2)/f_3(d^2)$. The rate of wear of the total ball charge equals the number of balls times rate of wear of the average ball. Thus

$$\text{rate of total ball wear} = \frac{f_3(D^2)}{f_3(d^2)} \cdot (dw/dt)$$

$$w_{t,\,total} = c_5 \cdot (1/d) \cdot n_p \cdot D^{2.5} \text{ lb per hr} \qquad [6]$$

which is the equation of ball wear in low speed mills.

In a mill running at a low speed, grinding is the result of rubbing action within the ball mass and between the ball mass and mill liners. When the speed of the mill is gradually increased toward the critical, the impacting effect of freely falling balls becomes increasingly prominent in comparison with the rubbing action. Reduction of ore takes place partly by rubbing, partly by impact. The share of the freely falling balls in the reduction of ore reaches its practical maximum at a speed somewhat less than the critical; at that speed grinding by rubbing has decreased to a low value. It may be reasonable to think that size reduction by freely falling balls should reach its theoretical maximum at the critical speed, if the fall of the balls were not hindered by the shell of the mill beyond the top point; grinding by rubbing would cease at the critical speed.

As a first approximation, wear of freely falling balls may be considered to be a homogeneous, linear function of the force at which they strike pieces of rock and other balls at the toe of the ball charge. The force equals mass times acceleration. The mass of a ball is a function of d^3 and its acceleration is a function of the peripheral speed of the mill. The wear of a single ball of size d representing the average ball in a ball charge will therefore be

$$w_f = f_4(F) = f_4(d^3) \cdot f_5(v). \qquad [7]$$

Indicating that $v = \pi\, D\, n$, and $n = c_3\, n_p\, 1/\sqrt{D}$, Eq. 7 becomes

$$w_f = c_6\, d^3\, n_p\, D^{0.5} \text{ lb per hr.} \qquad [8]$$

Total wear of the ball charge equals number of balls times the wear of the average ball. Number of

balls per unit of mill length equals $f_s(D^2)/f_s(d^2)$. The total ball wear will be

$$w_{f\ total} = c_7\, n_p\, D^{2.5} \text{ lb per hr.} \quad [9]$$

It is seen from Eq. 9 that the total ball wear of freely falling balls is independent of ball size.

It has been stated before that the ball wear of cascading balls is a function of the ball surface (d^2) and that of the freely falling balls is a function of the ball volume (d^3). It is obvious that the exponent of d at speeds between *low* and *critical* must have numerical values between 2 and 3. In the absence of more exact experimental data, the following assumptions are made:

1—At a speed 50 pct of the critical the ball wear is proportional to d^2.

2—At the critical speed, the imaginary action of the balls would be such that the ball wear would be proportional to d^3.

3—At other speeds the ball wear is a power function of d, the numerical value of the exponent q originating from the two given values as shown in Fig. 1.

In Fig. 1 the equation of the line is

$$q = 1 + 0.02\, n_p. \quad [10]$$

As can be seen, for $n_p = 50$, $q = 2$ and *for* $n_p = 100$, $q = 3$. At $n_p < 50$, $q < 2$. An extrapolation of the line gives the value of 1 for q-intercept.

In view of the fact that the line drawn in Fig. 1 is based on certain assumptions, Eq. 10 may also be expressed in the form of the general equation of a straight line as

$$q = c_8 + m'\, n_p, \quad [11]$$

where c_8 is the q-intercept and m' the slope of the line.

Ball wear in low speed (e.g., $n_p = 50$) mills was given in Eq. 6. It may be written as

$$w_{s\ total} = c_5 \frac{d^2}{d^3}\, n_p\, D^{2.5}$$

Wear of freely falling balls was given in Eq. 9. It can be written as

$$w_{f\ total} = c_7 \frac{d^2}{d^3}\, n_p\, D^{2.5}$$

When the exponent of the ball diameter d in the numerator of the above equations is replaced by its value as expressed in Eq. 10, the following relationship is obtained:

$$w_{total} = c_9 \frac{d^{(1\,+\,0.02\,n_p)}}{d^3}\, n_p\, D^{2.5} = c_9\, d^{(0.02\,n_p\,-\,2)}\, n_p\, D^{2.5} \text{ lb per hr.} \quad [12]$$

Eq. 12 gives the first approximation of mechanical ball wear at any mill speed based on the assumptions indicated above.

If the exponent of d is expressed in terms of Eq. 11, ball wear in its general form will be

$$w_{general} = c_9\, d^{(c_8\,+\,m'n_p\,-\,2)}\, n_p\, D^{2.5} \text{ lb per hr.} \quad [13]$$

The first approximation of ball wear per unit of ore ground will be obtained by dividing the equation of ball wear (Eq. 12) by the general equation of the tonnage of ore ground (Eq. 3).

$$w_s = \frac{c_9\, d^{(0.02\,n_p\,-\,2)}\, n_p\, D^{2.5}}{c_2\, (n_p)^m\, D^{(2\,+\,m/2)}} = c_{10}\, d^{(0.02\,n_p\,-\,2)}\, n_p^{(1\,-\,m)}\, D^{(0.5\,-\,m/2)} \text{ lb per ton.} \quad [14]$$

If $m = 1.0$, w_s will be independent of the mill diameter. In addition, it will not be influenced by the speed term $n_p^{(1-m)}$. However, owing to the fact that n_p occurs in the exponent of d, ball wear per ton of ore ground increases with increasing mill speed.

If $m > 1.0$, both the speed term $n_p^{(1-m)}$ and the mill diameter term $D^{(0.5-m/2)}$ will cause w_s to decrease with increasing values of n_p and of D. On the other hand, the term $d^{(0.02\,n_p\,-\,2)}$ indicates that ball wear per ton increases with increasing speed. From the point of view of ball consumption, it seems probable that in fine grinding it is advantageous to operate at low mill speeds, while the situation may be somewhat different, if not the opposite, in mills grinding coarse ore at high n_p values. In fine grinding ball mills, m = 1.0, but it may have values > 1.0 for coarse grinding ball mills.

According to Eq. 14, ball consumption in pounds per ton increases with decreasing ball diameter, other factors remaining constant. This relationship results from the fact that the effect of ball size on capacity is not considered in the general tonnage equation, Eq. 3. This effect of ball size can hardly be expressed by a simple formula for a general case. However, for ball mills grinding such feeds as rod mill discharge, the grinding capacity seems to be roughly proportional to $1/d^2$. In such a case, the equation of ball wear would be of the form

$$w_s = c_{11}\, d^{0.02\,n_p}\, n_p^{(1-m)}\, D^{(0.5\,-\,m/2)} \text{ lb per ton,} \quad [15]$$

indicating that reduction of ball size would result in overall reduction of consumption in pounds per ton.

Bond[3] has indicated that an index in terms of kilowatt hours per pound of metal wear furnishes a more useful criterion of ball wear than an index in terms of pounds (of metal) per ton of ore ground. The wear index is obtained by dividing Eq. 2 by Eq. 12.

$$\text{Wear index} = \frac{c_1\, n_p\, D^{2.5}}{c_9\, d^{(0.02\,n_p\,-\,2)}\, n_p\, D^{2.5}} = c_{11}\, d^{(2\,-\,0.02\,n_p)} \text{ kw-hr per lb.} \quad [16]$$

The wear index is independent of the size of the mill. The exponent of d in parenthesis indicates that the wear index decreases with increasing mill speed, in other words, for a certain numerical value of index, less energy is needed if speed is increased.

As a first approximation, liner wear should be proportional to the capacity of the mill, other factors remaining unchanged. Mechanical liner wear and reduction of ore are caused by the same forces acting inside the mill. According to Eq. 3, liner wear may be expressed by a similar formula as

$$w_{liner} = c_{12}\, (n_p)^m\, D^{(2\,+\,m/2)} \text{ lb per hr.} \quad [17]$$

Division of Eq. 17 by the general tonnage equation, Eq. 3, indicates that liner wear per ton of ore ground should be independent of n_p and of D. However, should exponent m in Eq. 17 be = 1.0 for liner wear but > 1.0 for the ore itself (Eq. 3), the equation of liner wear per ton of ore ground would be

$$w_{liner} = c_{14}\, n_p^{(1-m)}\, D^{(0.5\,-\,m/2)} \text{ lb per ton,} \quad [18]$$

indicating that liner wear would decrease with increasing mill speed and increasing mill diameter. As

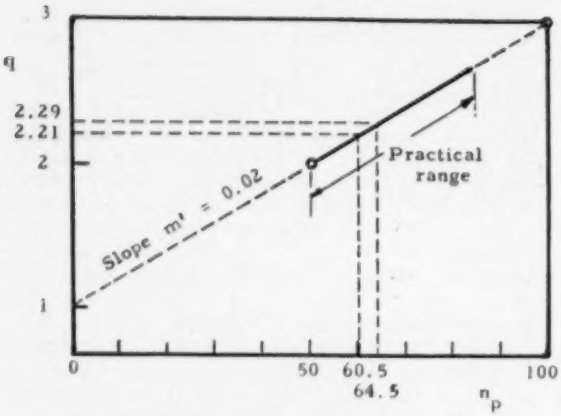

Fig. 1—Assumed relationship between q and n_p.

experimental evidence of liner wear in function of n_p and of D is nonexisting, opinions concerning liner wear cannot be supported by actual test data.

Discussion

The center of interest in investigations concerning ball wear has been the wear as a power function of ball diameter. Numerous studies have been focused on evaluations of the numerical value of exponent q of the ball diameter. Without going more in detail into the respective papers, the outcome of these studies may be summarized as follows: Ball wear proportional to the cube of ball diameter (d^3) has been reported by Davis,[3] and ball wear proportional to the square of ball diameter (d^2) by Ellis,[4] Prentice,[5] Garms and Stevens,[6] Norman and Loeb,[7] and Nordquist and Moeller.[8] The square rule is supported by Taggart[9] for cascading balls; for cataracting balls he gives the exponent as 3.5, probably by mistake. A variable figure such as 2.00, 2.21, and 2.29 is given by Bond[2, 10, 11] with the general remark that $d^{2.00}$ holds at lower and $d^{2.29}$ at higher mill speeds.[10]

As seen, the weight of evidence is strongly in favor of the d^2 rule. This rule, however, must be considered with certain precautions: 1—The actual n_p-value in tests reported is rarely given. 2—The change of n_p with liner wear may not have been appreciated. 3—Corrosion gives an emphasis on the surface rule, but its effect has not been evaluated.

If the evidence cited above is viewed in the light of the analysis presented in this paper, the square rule supports mechanical ball wear in mills running at a speed of about 50 pct of the critical. Exponents 2.21 and 2.29 by Bond would correspond to n_p values of 60.5 and 64.5, respectively, which may be representative of the American ball mill grinding practice. It is probable that in ball mills grinding coarse ore, running at higher speed and using larger balls, the exponent of d would be of the order of 2.2 to 2.5, while in all ball mills used for secondary and tertiary grinding at low speeds and equipped with small balls the square rule would hold in practice, because the experimental difficulties in the verification of the exact value of q for mechanical wear only would be hard to analyze and overcome.

From Fig. 1 it is obvious that at $n_p < 50$, q should be < 2. This possibility may be questionable, because no evidence of the existence of such an exponent seems to be available. On the other hand, whatever information is available, apparently no tests have been conducted at $n_p < 50$.

Investigations concerning rod wear are less extensive. In the controlling rod mill of the Tennessee Copper Co., rod wear is reported by Myers and Lewis[12] to be a function of d^3 (d being in this case the rod diameter) irrespective of mill speed. It would be of major interest to analyze the situation in terms of the parameters included in this paper for coarse-crushing rod mills such as the Sullivan mill.

In the outstanding study of grinding, the Lake Shore Staff[13] found a very useful information by reporting that the ball wear varies closely as the diameter of the mill to 2.6 power. Later, Norman and Loeb[7] observed that the rate at which individual balls wear was faster in mills of large diameter than in mills of small diameter and indicate that theoretically the wear rate of an individual ball will increase as the 0.6 power of the mill diameter. No description was given as to how they came to this theoretical conclusion. As was shown earlier in Eqs. 5 and 6, the relationship between these two concepts should be a simple one. In neither of the papers referred to, however, has the parameter of mill speed been included, although in certain tests at Lake Shore ball wear decreased with decreasing speed. It should be mentioned, too, that liner wear as a function of $D^{2.6}$ was also suggested by the Lake Shore staff.

Conclusion

This short review includes only the most essential information available through extensive investigations made by a number of mill men. It is apparent that the need exists for a basic relationship between mechanical ball wear and the parameters of ball size, mill speed, and mill diameter. The fundamental equation, Eq. 12, is presented here as a general rule to correlate these parameters. Although a basic equation could not be given that would apply in all instances, the rule may be modified for individual problems of grinding.

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aime NEWS

Fall Meeting Papers Show Great Promise

Definite commitments for papers to be presented at the Industrial Minerals Div. Fall Meeting at Lake Placid, N. Y., October 5 to 9, have started to come in.

Among the papers almost certain to be presented are: *Geology of the Adirondacks*, by Matt Walton; *Mineral Economics of Upstate New York*, by John A. Graham; *Geological Controls for Adirondack Mineral Deposits*, by A. E. J. Engle; *Anorthosite as an Adirondack Industrial Mineral*, by J. G. Broughton; *Geophysical Prospecting for Ilmenite in the Adirondacks*, by Leroy Sharon; and *Diopside and Wollastonite*, by Raymond Ladoo.

The committee in charge of securing technical papers hopes for additional manuscripts which will cover Gouverneur talc, garnet, slate, pyrite, and Sarasota waters.

A session dealing with Canadian topics is being planned.

Invitations to participate in the Fall Meeting as guests have been extended to the Mining Society of Nova Scotia, the Industrial Minerals Div. of the Canadian Institute of Mining & Metallurgy, and the Society of Economic Geologists.

Salt Lake City is reputedly one of the most beautiful cities of the West. It will be host to the Rocky Mountain Industrial Minerals Conference, October 29 and 30. Registration is slated for the 28th.

Salt Lake City

Salt Lake City, host to the Rocky Mountain Region Industrial Minerals Conference scheduled for October 28 to 30, promises to fulfill its reputation as an outstanding city. Plans underway for the meeting indicate that it will be one of the best of this year.

The Utah Section can easily be described as a group with imagination, typified by their recent staging of an authentic Hawaiian Luau, complete with leis, South Seas punch, and dancing to an Island orchestra.

Headquarters for the meeting will be the Newhouse Hotel. On the last day of the conference, football fans will be able to see two of the nation's consistently top teams, University of Utah and University of Idaho, in action.

The technical program, which promises to be a full one, is still in the formative stages, but should be rounded out soon.

Among the many papers to be presented will be ones dealing with iron and steel production at the Geneva Steel works; titanium; electric furnace production of elemental phosphorus; industrial water; natural gas; phosphate rock; and gypsum mining.

AAAS Sponsors Flotation Session

The American Assn. for the Advancement of Science is sponsoring a Gordon Research Conference on Flotation July 5 to 9, at Kimball Union Academy, Meriden, N. H.

Reservations are limited for the 4-day conference which features several outstanding speakers. Early application is encouraged. Requests for information and reservations should be addressed to W. G. Parks, Dept. of Chemistry, University of Rhode Island, Kingston, R. I.

N. Arbiter, chairman of the committee arranging the conference, notes that though there have been many AAAS conferences in the past, there has never been one dealing with the mineral industry field.

Panel speakers include: J. Morrison, National Research Council, Ottawa; H. A. Abramson, College of Physicians and Surgeons, New York; P. L. de Bruyn, MIT; A. M. Gaudin, MIT; N. Arbiter, Columbia University; H. R. Spedden, Union Carbide & Carbon Corp.; T. M. Morris, Missouri School of Mines; R. Schuhmann, Purdue University; and J. H. Shulman, Cambridge University.

One of the most talked about events at the Northwest Minerals Conference was the banquet staged on the last evening of the meeting. It followed three days filled with plant tours, technical sessions, and symposiums.

PACIFIC NORTHWEST CONFERENCE SCORES PORTLAND SUCCESS

The 1954 Pacific Northwest Metals and Minerals Conference at Portland, Ore., April 29 to May 1 started under a full head of steam with the Thursday plant tours and maintained the pace for the two days of technical sessions.

The affair is held annually at either Spokane, Seattle, or Portland. Originally organized as an industrial minerals conference, the meeting has grown to include iron and steel, physical and extractive metallurgy, and geology.

One of the most informative of the sessions, for students attending the conference, was the minerals industries education symposium moderated by Ira S. Allison, Oregon State College. Two other symposiums, groundwater and filtration of indus-

Between sessions, luncheons, and other activities groups gathered together at random to discuss the conference. Interest in technical sessions ran high throughout the two days devoted to them.

The Geology session proved to be one of the technical highlights of the conference. Among those who took part were, left to right back row, Messrs. Carey, Ruff, Sargent, Scott; front row, Mills, Bush, Trimble, and Bartholomew.

Assistant Secretary of the Interior Felix Wormser was the featured speaker at the Saturday evening banquet. He voiced his high hopes for the future of U. S. mining exploration.

The Mineral Industry Education symposium turned out to be most popular. Taking part in the discussion were, from left to right, standing: Donald L. Masson, F. R. Morral, D. A. Beetem, D. A. Pifer, Rex C. Beckstead, James F. McDivitt, M. A. Parker, and Ray L. Talbert; seated: Arthur M. Piper, H. W. Giles, George W. Gleeson, Donald W. Stotler, and Ira S. Allison, session chairman.

Arthur M. Piper of the U. S. Geological Survey holds forth at the speakers stand during the industrial waters symposium. He and John Robinson exchange views during the discussion.

Some of the people who attended the banquet pause during the festivities while the photographer snaps his shutter. Attendance at the affair was most gratifying to the committee in charge.

Robert C. Stephenson, Chairman of the Industrial Minerals Div., delivers an address during the Industrial Minerals luncheon.

trial gas, plus some 38 individual papers took all of Friday and Saturday to complete. Three technical sessions were in progress simultaneously Saturday, with overflow crowds the rule.

Felix E. Wormser, Assistant Secretary of the Interior for Minerals, delivered the keynote address at the grand banquet. He disclosed that the U. S. Geological Survey believes that just as many mineral deposits as have been found through surface outcroppings can be located hidden beneath the surface. Mr. Wormser emphasized that new and improved techniques will be needed to make the discoveries. He also opined that utilization of lower grade deposits will greatly expand mineral reserves because lower quality or concentration of material means greater tonnage.

Mr. Wormser also took aim at government regulation of business in time of stress, stating that competitive enterprise should be preserved even though not all can win practicing it.

Despite the absence of an official ladies' auxiliary, some 50 ladies made an appearance at various social events and three specially arranged tours. Thirty-three students and student associates representing eight Northwest colleges registered for the conference. Six University of Oregon undergraduates contributed to the banquet with an impromptu bit of group singing, aided by a charming accordian player.

CIM General Meeting Host to 1600

Close to 1600 members and guests, including some 300 ladies, attended the 56th Annual General Meeting of the Canadian Institute of Mining and Metallurgy in the Sheraton-Mount Royal Hotel, Montreal, April 26 to 28. This was a record turnout, and both the technical and social features of the meeting fully warranted the large attendance. More than 50 visitors came from "south of the border, down USA way." The technical features of the CIM annual meetings have been expanded greatly in recent years. As many as six concurrent sessions were scheduled, covering all the major phases of mineral technology.

One of the most generally interesting and competently prepared papers was that given at the concluding session by John Convey, Director of the Mines Branch at Ottawa, on *Uranium in Canada*. Doubtless many other papers were equally notable but your reporter was not ubiquitous. We did have an opportunity to see an exceptionally fine new motion picture in color on tunnel driving, entitled *Power from Niagara*.

Dean A. E. Flynn, president of the CIM, presided most capably at several functions. Montreal's famous mayor, Camillien Houde, welcomed the gathering at the opening luncheon and personally greeted the ladies at a tea at the Chalet on top of Mount Royal. President Reinartz, of the AIME, brought greetings from the CIM's sister society at the Tuesday luncheon. The annual dance, which the CIM features as a separate event from the annual banquet, was especially enjoyable.

An item of interest in the business sessions was approval of a proposed bylaw amendment to allow women to be members of the CIM on an equal status with men, as has been the case with the AIME since it was founded. Heretofore, a CIM bylaw has stated, "To be eligible for enrolment as a Member an applicant shall be a man not less than 27 years of age . . ." The word "man" is now being changed to "person," much to the satisfaction of several otherwise qualified persons who have had the misfortune, in this particular connection, of being members of the female sex.

All in all, it was the best meeting of the Canadian Institute that your reporter (an old CIM member himself) has yet attended, which is no small praise. C. Gerow, the Secretary, is to be complimented on a particularly smooth operation, to which his small but competent staff, including especially the Hazeltons and Assistant Secretary E. C. Allingham, contributed much.—E.H.R.

Committee of Five to Study Building

The problem of what kind of a building to erect for the national engineering societies, and where to put it, has been placed in the hands of a "Committee of the Five Presidents," composed of the current presidents of AIME, ASCE, ASME, AIEE, and AIChE. Inspection trips have recently been made to several proposed sites in Chicago and immediate vicinity, and to a site on the Stevens Institute campus in Hoboken, N. J. Interest has also been aroused by a proposal from Robert Moses, Commissioner of the New York City Dept. of Parks, that the societies consider a site of 1.3 acres in a slum-clearance project in the Columbus Circle area. The specific location suggested is at the northeast corner of 60th and Amsterdam Ave., adjacent to the proposed new Metropolitan Opera House. A review is being made of all offers and proposals so far made, which will be considered by the Committee of the Five Presidents.

A 48-page directory of AIME officers, local sections, branches, divisions, student chapters, and committees will be mailed to all paid-up AIME members in June. No complete all-Institute directory will be published until the spring of 1955. The last issue, corrected to Sept. 1, 1952, is now out of print.

Ayer Receives Medal

At a dinner meeting in the ballroom of the Waldorf Astoria Hotel on April 14, Frank A. Ayer was presented with the Egleston Medal. The dinner was sponsored by the Columbia University Engineering School Alumni Assn. The Medal was founded in 1939 on the 75th anniversary of the Columbia School of Mines in memory of Prof. Thomas Egleston, pioneer in engineering education and a member of the Columbia faculty from 1863 until the time of his death in 1900. It is awarded annually to an alumnus who has distinguished himself either in furtherance of his branch of the profession, in development of processes or techniques, or in application of engineering principles. Frank Ayer, an AIME Member since 1914, received his E.M. from Columbia in 1911. For many years prior to 1934 he was with Phelps Dodge. He then had several years' experience with Roan Antelope in Northern Rhodesia, and more recently he has been associated with Copper Range in its development of the White Pine deposit.

Two New Sections Gain AIME Approval

Two new Local Sections of the AIME were approved at the April 21 meeting of the Executive Committee of the AIME Board of Directors.

One, to be known as the Arkansas Section, takes the place of the former Arkansas Subsection of the St. Louis Section. It includes substantially that area north of a line extending across the state east and west of Hot Springs, 54 counties in all. The remaining southern area of the State is included in Lou-Ark Section territory.

The other, to be known as the Colorado Plateau Section, takes the place of the former San Juan Subsection of the Colorado Section. The new Section will include all AIME members (except Petroleum Branch members, who are members of the Denver Petroleum Section) in the following counties of the state: Delta, Dolores, Garfield, Gunnison, Hinsdale, La Plata, Mesa, Moffat, Montezuma, Montrose, Ouray, Pitkin, Rio Blanco, Routt, San Juan, and San Miguel. This includes the San Juan area and the new uranium territory.

Five counties of Texas, not heretofore included in any Local Section territory, have been added to the Southwest Texas Section, as follows: Blanco, Burnett, Gillespie, Llano, and Mason.

Territory of the new San Joaquin Valley Local Section has now definitely been established to consist of the following counties in California. Fresno, Kern, Kings, San Luis Obispo, Santa Barbara, and Tulare. Some of this area had formerly been included in the territory of either the Southern California or San Francisco Sections.

AIME Research Committee Formed

An AIME Committee on Research has been established, with the following personnel: Francis B. Foley, chairman; S. S. Cole, A. M. Gaudin, Elmer R. Kaiser, E. P. Pfleider, A. J. Phillips, R. E. Salvati, Earle E. Schumacher, and J. E. Sherborne. The stated functions of the Committee are 1) to review, at least annually, progress on the Engineering Foundation projects that the AIME recommends; 2) to encourage submission to Engineering Foundation of new projects in the various fields of the Institute; 3) to review the Rules of Administration of the Engineering Foundation and suggest any desirable changes. Other specific duties may be assigned the Committee from time to time in the future. AIME members wishing financial support of research work should get in touch with the Committee.

Utah Section Sponsors Panel Discussion: Engineering Education for the Mineral Industries

by J. M. Ehrhorn*

Engineering education designed to please everyone has not and probably will never be developed. The purpose of this panel discussion sponsored by the Utah Section was to give industry and the educators at the University of Utah an opportunity to discuss the problem.

The panel was conducted under the direction of G. Homer Durham, vice president of the University of Utah. Mr. Durham called attention to the challenge to the university in making the College of Mines and Mineral Industries one of its best. He welcomed the opportunity to discuss engineering education.

The first panel speaker, W. G. Rouillard, manager, Garfield Smelter, American Smelting & Refining Co., spoke of the needs of academic training particularly for metallurgy. He stressed the importance of a thorough knowledge of chemistry, physics, and metallurgy. Mathematics in his opinion serves valuable training in mental development. A sufficient knowledge of engineering mechanics is recommended so that the metallurgist will not be confused by experts. Mr. Rouillard emphasized the need to be articulate both in writing and speaking. The requirements for a metallurgist to succeed include the ability to enjoy work, the willingness to perform arduous jobs and work long hours, and the ability to get along with people. Training in the humanities should be included.

F. Cooper Green, assistant general manager, Utah Div., Kennecott Copper Corp., who followed Mr. Rouillard, posed the problem of the amount of academic work that should be required. He pointed to the changes that constantly develop in the mineral industries, and the importance of labor, industrial, and public relations. Mr. Green asked whether engineering education should be lengthened one or even two years. He indicated that if a formal college training program were to include an expanded set of requirements, the 4-year course would have to be lengthened. The alternative is to cut and substitute to conform to the 4-year course. He emphasized that such related training as labor contracts, business training, cost accounting, and the ability to get along with people are things the engineer needs. In order to add that kind of training, courses such as mathematics would be dropped.

John R. Lewis, head, Dept. of Metallurgy, University of Utah, spoke of the curriculum for mining engineering at the school. He outlined the engineering curriculum of 1901 at the University and the present program. The requirement for graduation in mining engineering now is 231 quarter hours compared with 183 quarter hours for liberal arts students in the University College.

The present curriculum compares favorably with one suggested by a committee headed by J. D. Forrester, Missouri School of Mines, and published in the January 1954 issue of the *Journal of Engineering Education*. The two curricula are compared in the table.

Comparison of Curricula by Percentage of Alloted Time

Course of Study	Journal of Engineering Education	University of Utah
Basic Sciences	28	29
Engineering and Science Service Courses	18	12
Humanities, Social Science	15	13
Professional fundamentals	15	22
Technical electives	19	22
Other electives	5	
Military Science		2

Mr. Lewis pointed out that the present 4-year mining engineering course is a difficult one and cannot be expanded to include management, personnel, and other desirable courses unless the program is spread over 5 or more years or some of the present requirements are eliminated.

Grant W. Schaumburg, works industrial engineer, Columbia-Geneva Div., U. S. Steel Corp., emphasized the importance for the engineer to acquire knowledge other than engineering. The rudiments of business, what makes a corporation, and that bigness is not synonymous with badness are important to an engineer. Mr. Schaumburg feels that all college graduates lack training they would like to have. He stated that formal college training could go on indefinitely, but a line must be drawn. The engineer should be able to fare with what he has when he graduates. He emphasized that speaking and writing should receive greater emphasis.

The next speaker, Byron E. Grant, assistant to vice president and general manager, U. S. Smelting Refining & Mining Co., related his experience on the Public School Survey Commission which summarized its study with a recommendation that more reading, writing, and arithmetic should be taught in high school. He feels that colleges aim at specialization. A study of graduate engineers shows that 50 pct are in management fields instead of engineering. He emphasized that if colleges specialize, the fields of geology, surveying, mechanics, metallurgy, electricity, cost analysis, efficiency, consultation, and industrial engineering cannot be covered to train the engineer for management. Colleges in his opinion should rub off some specialization and substitute more generalization.

Armand J. Eardley, head, Dept. of Geology, University of Utah, called attention to the similarity in the discussions by industry members and educators. Both are interested in developing leadership. He emphasized the importance to the engineer of personality, enjoying his job, and willingness to perform beyond the call of the job. These traits cannot be instilled in everyone. The best that any school can do is develop the characteristics that lie within an individual. Mr. Eardley has found that the greatest successes are the average students who like work and people. They are not outstanding academically. Experience has shown that a person inspired toward an end will overcome deficiencies and specialize to the necessary degree.

The seventh panel speaker, Dorsey Hager, consulting petroleum geologist, emphasized that a university is not a trade school. The purpose of the university should be to produce a well-rounded man. He considers extracurricular activities important. The engineer should be trained both in speaking and writing. He considers a college education only an introduction to a chosen field. Universities should concentrate on fundamentals.

After a question-and-answer period, in which the audience and the panel participated, Mr. Durham concluded the discussion with a summary. He traced the development of the mineral industry to its present state of complexity. Industry today needs both specialists and well-rounded men and educators face the problem of reconciling these needs. The problem of the university is both in the quantity and quality of courses. The financial limitations are severe. The University of Utah is proud of the quality of its faculty.

Social sciences can help develop fundamental attitudes important to life. One of the problems of the university is the secondary education of its students. Of seven objectives of the Salt Lake City high schools only one is for college preparation.

* Vice Chairman, Utah Section AIME, and Industrial Development Director, U. S. Smelting Refining & Mining Co.

Around the Sections

• The **Arizona Section** took over the entire mezzanine floor of the Pioneer Hotel in Tucson for its recent Annual Meeting. Technical sessions were held during morning and afternoon. The cocktail hour, dinner, and dance were held that evening. Registration totaled 495 members, guests, and students. F. M. Stephens, Arizona Mining Geology Div. Chairman, presided at the group's session. Some 65 persons heard four papers presented. They were: *A Folded Overthrust Fault and Sediments Derived from the Scarps of Overthrust and Normal Faults in the Tortilla Mountains, Arizona*, by P. C. Benedict and Robert B. Hargraves; *Structure Plans of Ore Districts*, by Evan B. Mayo; *Industrial Minerals of the Navajo Country, Arizona-Utah*, by George A. Kiersch; and *Geology and Ore Occurrences of the Flux Mine, Santa Cruz County, Arizona*, by Paul I. Eimon. The section's Underground Mining Div. met under the chairmanship of Robert C. Weed. Papers were presented on *Drifting at San Manuel*, by H. I. Ashby, and *Shaft Sinking at San Manuel*, by Charles L. Pillar. Mr. Pillar has been elected Section Division Chairman.

A paper on rotary drilling operations by A. M. Watkins and *The Use of Signals and Power Switches in the Rail Haulage System at Ajo*, by E. T. Seaberg, were given at the Open Pit session. Warren T. Smith served as Chairman. J. C. Van de Water was chosen Open Pit Chairman for 1954. Halder J. Rex called the Ore Dressing session to order. Reports on *Commercial Scale Plants Producing Acid or Ferric Sulphate by Autoxidation*, by Harmon E. Keyes, and *Leaching of Vanadium and Uranium Ores on the Colorado Plateau*, by E. J. Duggan were presented. George P. Sewell, Jr. will serve as Division Chairman for the year.

Materials handling and mechanization at smelters was the topic of the Smelting Div. meeting. Some 36 persons heard the paper on *Mechanical Handling of Blister Copper at Hayden*, by H. G. Simmons. L. L. McDaniel, Phelps Dodge Copper Corp., Morenci, Ariz., described the use of mechanical equipment at his plant. Other materials handling topics were broached by H. F. Lindsey and J. W. Byrkit. L. L. McDaniel was elected AIME group Chairman.

Special guests at the banquet were Richard A. Harvill, president, University of Arizona and T. B. Counselman, AIME Director.

• The regular spring meeting of the **Pennsylvania Anthracite Section** was held at Genetti's in downtown Hazelton, with Milton S. Eisenhower, president of Pennsylvania State University as principal speaker. Edward G. Fox, president of Philadelphia & Reading Coal & Iron Co., presided at the meeting.

• Warren Hastings, mine superintendent of the Sterling mine, Ogdensburg, N. J., traced the development of the Friedensville mine of the New Jersey Zinc Co. at the last meeting of the **New York Section.** Mr. Hastings has been in charge of development at Friedensville.

• Featured speaker at the dinner-meeting of the **Chicago Section,** recently, was William Rostoker, senior metallurgist for Armour Research Foundation. He spoke on *The Development of Vanadium Base Alloys.*

• The **Southern Sierra Subsection** heard C. L. Dickinson, plant advisor of the American Potash & Chemical Corp., Trona, Calif., speak on production of chlorine and caustic soda from a salt solution. He illustrated his talk with slides.

• A sound-color film on the Orinoco mine project in Venezuela, written and produced by Richard Finnie, historian, Bechtel Corp., San Francisco, was shown to members of the **San Francisco Section.** The film showed the monumental task faced in bringing the mine into production. After the film, Earl English, vice president, Bechtel International Corp., presented the engineering side of the story. Larry Wright briefed the audience on geological data of the area. The program was arranged by Mack C. Lake, president of the Orinoco Mining Co., at the time the project was placed in production.

• The **San Juan Subsection** discussed a proposal to select a full section to replace the present subsection. Following the discussion a program of technical papers covered: the Atomic Energy Commission; the chemistry of the salt roasting step; the new tungsten concentrator at Glen, Mont.; and other subjects. Dinner and dancing topped the activities.

• AIME President Leo F. Reinartz paid the **St. Louis Section** a visit not too long ago, giving an account of general plans for his term of office. He also discussed local section problems with members. The section held its student conclave at St. Louis University, with 32 students attending the luncheon at Davis-Shaughnessy Hall. The six recent graduates who discussed the subject, *The First Five Years*, were Marvin Winkel, Robert Morris, Clarence J. Moser, Rudolph Valenta, James W. Hart, and S. Clarke Judge.

• The **Tri-State Section,** meeting at Baxter Springs, Kan., was given a rundown on equipment manufactured by the Byron-Jackson Pump Co. of Los Angeles by James Ladkin and Robert Hicks. The firm representatives demonstrated the equipment from a B-J display truck.

• Ernest N. Patty, president of the University of Alaska, spoke before members of the **Alaska Section,** meeting at the University of Alaska. Maurice Butler presided over the dinner-meeting.

• Joint meeting of the **Anderson-Carlisle Technical Society** and the **Montana Section** took place recently in the physics lecture room in the new Physics-Petroleum Bldg. at Montana School of Mines. Frank A. Linforth, assistant to the vice president of Anaconda Copper Mining Co., Butte, Mont., spoke on *Whence Comes the Energy of the Hydrogen Bomb?* The Anderson-Carlisle Technical Society is the AIME student chapter at the Montana School of Mines.

• The **Colorado Section** held its final meeting of the season during May, but expects a lot of activity this month. **Minerals Beneficiation Subsection** holds its meeting at Climax June 12, with a banquet slated for Leadville. The Woman's Auxiliary is staging its biennial dinner dance at the Lakewood country club in June.

• About 90 members, wives, and guests of the **Lehigh Valley Section** gathered at the Saucon Valley Country Club, near Bethlehem, Pa., for the annual spring dinner dance. Mrs. W. S. Cumings and Mrs. R. T. Gallagher, chairman and treasurer respectively of the dance committee, handled arrangements.

• The Pend Oreille Mine & Metal Co. presented a program on geology, mining, and milling at its plant to about 38 members of the **Spokane Section.** John Fritts, company geologist, described location and geological characteristics of the mine; and Loren B. Billings, mine superintendent, told the group that the mine has been converted to a 90 pct trackless operation. Three students from Wahington State College made the long drive from Pullman to hear the lectures.

Around the Sections

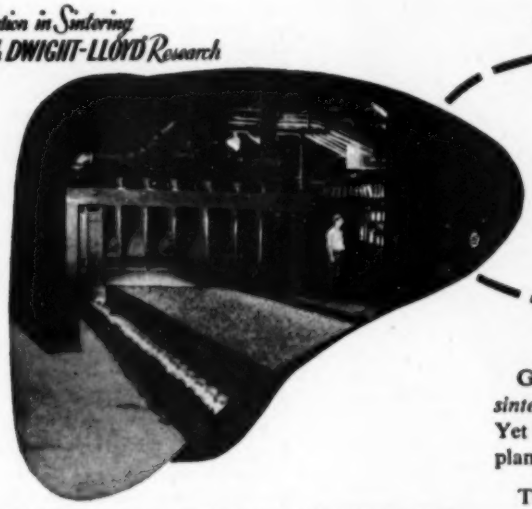
• **Baldwin-Lima-Hamilton Corp.'s film,** *The Big Lift,* **tells the story of the excavating equipment industry, and Lima shovels, cranes, and draglines. The movie contains a father and son plot. Requests for scheduling are handled by B-L-H Sales Promotion Dept., at Lima, Ohio.**

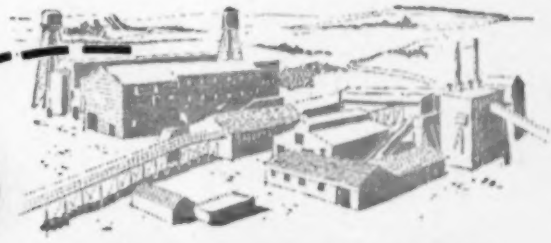
• **Westinghouse Air Brake's new Kodachrome motion picture,** *At this Moment,* **captures all the excitement of life on the railroads. The film is well plotted. The scene moves across the Mississippi country and the Middle West, over the great plains, and out to the Pacific Coast, giving an impressionistic view of the nation's economic activity. For more information contact the Publicity Dept., 2821 East Grand Blvd., Detroit 11, Mich.**

• **Ultra high-speed color motion pictures showing what actually happens during flashovers in locomotive generators have been produced by General Electric Co., Schenectady, N. Y. The film illustrates the air curing process of making a commutator electrically clean. Other procedures used to reduce number of flashovers are also covered in the 20-min. reel.**

General Manager A. P. Morris, Kennecott Copper Corp., Ray, Ariz., announced that the company's annual $1000 scholarship has been split between two students. One of the students, Richard D. Mendoza, watches his partner, student Charles B. Leonard, explain his work at the University of Arizona in metallurgy. J. B. Cunningham, standing, head of the Dept. of Mining and Metallurgical Engineering, and Thomas G. Chapman, left, dean of School of Mines, and Mr. Morris seated, center, look on.

Revolution in Sintering Through DWIGHT-LLOYD Research





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*Compound Discharge Curve** — Eliminates spillage, controls pallet drop, reduces pallet wear.

Upper and Lower Windboxes —for up-draft or down-draft operation.

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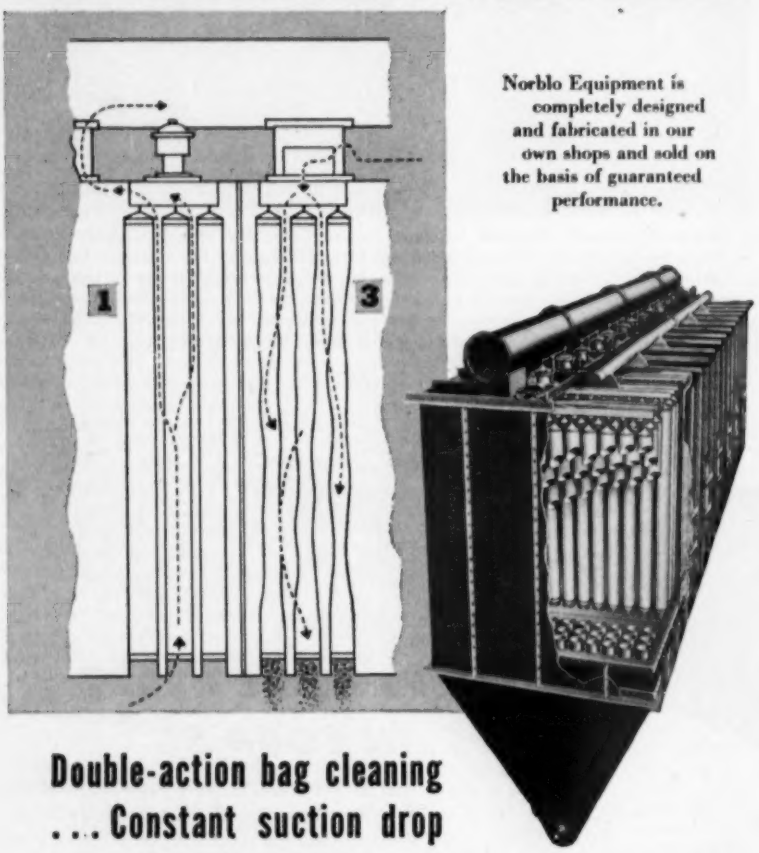

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AIME Recommends Projects for Research

Four research projects have been recommended by the AIME for sponsorship by the Engineering Foundation in the coming year.

EF 104. Comminution, in charge of R. J. Charles at MIT. The work is being done on two problems: to ascertain accurately what physical changes take place in substances that have undergone mechanical size reduction; and to determine precisely how these changes are accomplished. Last year a method of fine size analysis was developed, involving size fractionation by elutriation in a centrifugal field. Particles less than 1 micron can be separated efficiently and quickly from an initial sample containing particles of all sizes.

Other projects include: **EF 80— Quenching Investigations; EF 97— Diffusion in Steel;** and **EF 32— Alloys of Iron Research.**

AIME Invited To Geology Congress

At the Annual Meeting, Raul de la Peña announced that Mexico would be host to the 20th International Geological Congress in 1956 and he invited all AIME Members interested to begin to make plans to attend. He stated that the subjects will include "vulcanology, petroleum geology, geohydrology, relations between tectonics and sedimentation, modern ideas on the origin of minerals, intrusive igneous rocks and their relation to structural geology, geophysics as applied to the geological problems, and all phases of general geology." There will be two kinds of excursions, those of pure geological interest and those to the principal mining and petroleum districts of Mexico. Twenty-four field trips are already tentatively planned.

UPADI Completes Plans for August

The Pan American Federation of Engineering Assns. (UPADI) has virtually completed plans for the meeting next August in São Paulo, Brazil. AIME delegates and alternates will include Sherwin F. Kelly, Guy V. Woody, and Carl Westphal. All AIME Members are invited to attend. Business sessions will take place on August 2 to 6, followed by a trip to Iguacu Falls by plane and to Rio de Janeiro. The meeting will be held jointly with the World Power Conference and the Inter-American Association of Sanitary Engineering. Particulars will be supplied to interested AIME members by the Committee on International Relations, Engineers Joint Council, 29 W. 39th St., New York 18, N. Y.

Personals

John L. G. Weysser, consulting mining engineer, Pottsville, Pa., recently completed an engagement in Korea as consultant to the United Nations Korean Reconstruction Agency on its program to increase coal mine production. Mr. Weysser is now examining mines in Japan.

Glen W. Wensch has been appointed the metallurgical engineering representative of the Vitro Corp. of America in the atomic power reactor project now under study by 26 associated firms, led by Dow Chemical Co. and Detroit Edison Co. Mr. Wensch joined Vitro in February after serving for 2 years as chief of the materials branch of the Atomic Energy Commission at the Savannah River operations office in Georgia.

Richard I. Salberg has resigned as mine superintendent of MacIntyre Development of National Lead Co., Tahawus, N. Y., to join the Marcona Mining Co., San Juan, Peru.

Edwin H. Crabtree, Jr., for the past 7 years director of milling, Eagle-Picher Co., Mining & Smelting Div., Miami, Okla., has been named deputy manager, Operations Office, Atomic Energy Commission, Grand Junction, Colo.

W. J. PARTON

W. J. Parton of Lanford, Pa., has been elected president of Lehigh Navigation Coal Co. He succeeds **Glenn O. Kidd,** Wayne, Pa., who resigned. Mr. Parton joined Lehigh in 1941 as a member of the engineering corps and shortly thereafter was named preparation engineer in charge of a research project on fine size coal recovery methods. He is past president of the Anthracite Chapter, Pennsylvania Society of Professional Engineers and the author of a number of technical papers.

W. D. McMillan is now with U. S. Bureau of Mines, Denver. He was with Cuban Nickel Co., Nicaro, Oriente, Cuba.

C. C. HUSTON

Charles C. Huston, president of the Canadian Institute of Mining and Metallurgy for 1954 to 1955, has been an AIME member since 1946. He was born in Ypsilanti, Mich., in 1908. The son of a mining engineer, he learned to speak and write Spanish in Mexico and Nicaragua. After graduating from Michigan College of Mining and Technology in 1930, he worked as a shift boss in Chile for Braden Copper Co. He spent two years in Alaska with Fairbanks Exploration Co. and went to Canada in 1934 as assistant manager for Central Patricia Gold Mines Ltd. In 1935 he became manager of Mosher Long Lac Gold Mines Ltd. and of Robb-Montbray Mines Ltd. He joined Macassa Mines Ltd. the following year. Mr. Huston became a Canadian citizen in 1939 and during World War II worked as a supervising engineer for the Allied War Supplies Corp., as assistant to the general manager of the Scarboro Munitions Plant, and as a chief mining engineer for a Brazilian project of the FEA in Washington, D. C. In 1945 he returned to the head office of Macassa Mines and later started a general consultant practice in Toronto. Mr. Huston has served on the CIM Council since 1945, first as vice president and then as a member of the executive committee. He is a member of the Professional Engineers of Ontario and a charter member of the Pan-American Institute of Mining Engineers and Geologists.

John D. Noll has been released from the U. S. Army and has returned to Oliver Iron Mining Div., U. S. Steel Corp. He is finishing the training program he began in 1951. Mr. Noll was a lieutenant with the 21st Engineers, C Battalion.

Sherwin F. Kelly was named chairman of a committee to produce a casebook on mining geophysics at the recent CIM annual meeting. The volume will appear in time for the VI Empire Mining Congress. Mr. Kelly is also chairman of the AIME Committee on Cooperation with the CIM.

George V. Dutney has been appointed special assistant to **Robert E. Friend,** president, Nordberg Mfg. Co., Milwaukee. Mr. Dutney, who will make his headquarters in New York, comes to the company from Johns-Manville Corp.

J. R. Van Pelt, president of Montana School of Mines, will be the official delegate of the AIME at the annual meeting of the American Society for Engineering Education to be held June 14 to 18 at the University of Illinois, Urbana, Ill. More than 1500 engineering educators will attend this conference which will analyze all phases of engineering education.

Harlow J. Reed and **Thomas R. Young** have been elected to partnership in Singmaster & Breyer, New York. Mr. Reed joined the company in 1946 after 3 years with the Chile Copper Co., Chuquicamata, Chile, as smelter superintendent of the electrolytic plant. Mr. Young was formerly production supervisor of Du Pont's tetraethyl lead plant.

RICHARD C. COLE

Richard C. Cole, who was assistant to the manager of the ore purchasing dept., American Smelting & Refining Co., is plant manager, Vitro Uranium Co., Salt Lake City. Vitro Uranium Co., a division of Vitro Corp. of America, processes uranium ore for the AEC on the Colorado Plateau.

George A. Shoemaker, executive vice president of Pittsburgh Consolidation Coal Co. and president of Mathies, Renton, and Harmar coal companies, has been elected to the board of directors of Dravo Corp., Pittsburgh. Mr. Shoemaker, a graduate of Pennsylvania State University, has been associated with the coal industry since 1930.

ROGER V. PIERCE

Roger V. Pierce, mining consultant, Salt Lake City, is to receive the professional degree of Engineer of Mines at the commencement exercises on June 11 at the Montana School of Mines, Butte. Mr. Pierce was a graduate in mining engineering from Montana School of Mines in 1935.

Henry J. Franey has resigned as superintendent of International Metallurgical Chrome Corp., San Luis Obispo, Calif. He is now in Santa Barbara, Calif., and is employed as a safety engineer by Coker Construction Co.

John F. Thompson, chairman of the board, International Nickel Co. of Canada Ltd., has announced that **Henry S. Wingate** has been elected president and **F. M. A. Noblet** has been elected treasurer. **Paul D. Merica,** former president, and **William J. Hutchinson,** former treasurer, will continue to serve the company on important projects and as consultants. **J. Roy Gordon** will transfer from Copper Cliff, Ont., to New York. Mr. Gordon, who joined Inco in 1936, is a director and vice president. **Ralph D. Parker** has been elected general manager of Canadian operations. He continues as assistant vice president. **Walter C. Kerrigan** has been made assistant to the new president and **Herbert G. Fales,** assistant to the chairman.

W. Alton Jones, chairman of the board of directors, Cities Service Co., recently saw his wife smash the traditional bottle of champagne across the bow of the new 38,000-ton tanker that bears his name. Christened at Newport News, Va., the *S.S. W. Alton Jones* is the second largest tanker ever built in the U.S.

Robert H. Lane of the engineering dept., International Minerals & Chemical Corp., Carlsbad, N. M., has been advanced to geologist. **Howard J. Husing** has been named mine surveyor.

J. T. SHERMAN

John T. Sherman has been named head of the metals process section of the sales dept., Chemical Construction Corp. Research conducted by this section has resulted in the development of techniques for extracting metals and metallic compounds from ores, concentrates, alloys, and scrap by new hydrometallurgical processes. Mr. Sherman will negotiate agreements covering the installation of plants to utilize these recovery methods.

Harold L. Price, formerly superintendent, Glen Alden Coal Co., Audenried, Carbon County, Pa., is now a mining consultant and president of Price Coal Co., Pottsville, Pa.

David L. Springston has been appointed sales engineer at Columbus, Ohio, for the WEMCO Div., Western Machinery Co. Mr. Springston will handle sales and servicing of equipment for coal preparation, mineral processing, sand and gravel, and chemical industries.

Kirtley F. Mather, professor of geology and curator of the Geological Museum, and **Russell Gibson,** associate professor of economic geology, will retire from Harvard University at the end of the academic year. Mr. Mather, who has been on the faculty since 1924, is a former president of the American Assn. for the Advancement of Science. Mr. Gibson has taught at Harvard since 1927. He has done extensive work for the U. S. and Colorado Geological Surveys, as well as field work in South America, Mexico, and China.

Robert W. Hughes, in addition to his duties as general manager Miami Copper Co., Miami, Ariz., has been elected a vice president and director.

W. J. Roberts, Sr., president of Traylor Engineering & Mfg. Co. since 1918, has been elected chairman of the board. Succeeding Mr. Roberts as president is **Jesse K. Mair,** formerly secretary and treasurer, who has been with the company since 1918. In addition to being president, Mr. Mair will also continue as treasurer of the Traylor Co. and as president of Cement Gun Co.

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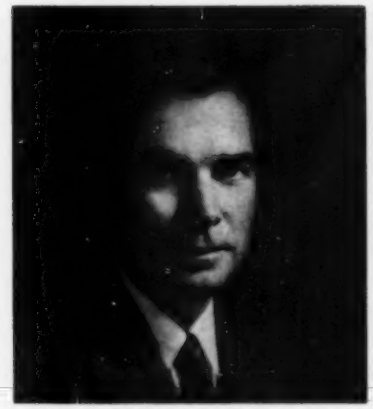

FRANK COOLBAUGH

WESTON G. THOMAS

Arthur H. Bunker, president Climax Molybdenum Co., has announced the election of **Weston G. Thomas**, as executive vice president; **Frank Coolbaugh**, vice president—western operations; **Alvin J. Herzig**, vice president—research; and **Wallace Macgregor**, as treasurer. **Carl M. Loeb, Jr.**, has resigned as vice president in charge of sales and research, but will remain as a member of the board of directors and as chief technical adviser to the company.

Harley A. Coy, general superintendent, American Zinc Co. of Tennessee, Mascot, Tenn., has announced the promotion of **James H. Polhemus**, metallurgist, to the position of assistant mill superintendent.

Neilsen B. O'Rear, for the past 12 years an information officer with the U. S. Bureau of Mines, Washington, D. C., has been appointed the new public information officer for the Grand Junction Operations Office of the AEC.

Leon D. Keller and **Edward F. Porter** have been transferred to the new office The Dorr Co. has opened in Virginia, Minn. Mr. Keller was in Dorr's St. Paul office and Mr. Porter was on the staff of the Evanston, Ill., office. Both men are graduates of Colorado School of Mines.

Andrew V. Corry, Minerals Attaché, U. S. Embassy, New Delhi, India, is completing his tour of duty. His successor will be **Franke E. Noe, Jr.**, now with the U. S. Embassy in Mexico City.

R. Maurice Tripp has resigned as an officer of Research Inc., Dallas, in order to devote more time to the scientific development of mineral exploration. He will continue with the company as a consultant. **Thomas R. Shugart** is now president

G. B. Langford, professor of mining geology and head of the Dept. of Geological Sciences, University of Toronto, has told the story of Canadian mineral industry in *Out of the Earth* just published by University of Toronto Press. (*See page 566.*)

George P. Sawyer has retired as vice president, Cerro de Pasco Corp., New York, but will continue as a member of the board of directors. Mr. Sawyer first joined Cerro de Pasco in 1917. He has been vice president since 1938.

Jacob Blecheisen has been elected president and director of Rosiclare Lead & Fluorspar Mining Co., Rosiclare, Ill.

William T. Mahood has been appointed manager of the contractors section, explosive dept., Atlas Powder Co., Wilmington, Del.

Donald McGregor Stephens of Winnipeg, Manitoba, is president of the Engineering Institute of Canada. He succeeds **Ross L. Dobbin** of Peterborough, Ont. Mr. Stephens is chairman and general manager of the Manitoba Hydro-Electric Board and president and general manager of the Winnipeg Electric Co. He served as deputy minister of the Manitoba Dept. of Mines & Natural Resources from 1938 to 1951.

Herbert E. Jones, Jr., is executive vice president, Amherst Coal Co., Reed, W. Va.

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Obituaries

Appreciation of

Fernando C. Fuchs

by Alberto Brazzini

We regret to record the death in Lima on February 21 of Fernando C. Fuchs, 83, distinguished Peruvian mining and industrial engineer, financier, and former Minister of State. Engineer Fuchs contributed important services to the Peruvian mining industry and also shared his knowledge as a member of the faculty of the Engineering School of the University of San Marcos, in Lima. He investigated the principal mining regions in Peru, and his accurate reports will always be a valuable source of information.

Mr. Fuchs was a member of our Legion of Honor, Class of 1902. In celebration of this event he was guest of honor at a dinner-dance given by the Lima, Peru, Local Section of the AIME on June 28, 1952.

The pioneering and outstanding work of Fernando C. Fuchs has furthered the development of Peruvian natural resources, and his life was an example of unselfish devotion to his profession and his country.

Francis H. Brownell (Member 1941), former chairman of the board of American Smelting & Refining Co. died Mar. 8, 1954. He was awarded the Charles F. Rand Medal in 1950 for "distinguished achievement in mining administration." Mr. Brownell was born in Little Compton, R. I., in 1867. He received his A.B. degree from Brown University in 1888 and then studied at Columbia Law School. After being admitted to the bar in New York State, he moved to Tacoma, Wash., practicing law there and later in Everett, Wash., and Seattle. In 1891 Mr. Brownell became attorney for the Monte Cristo mines and for the Everett smelter. When the latter was acquired by Asarco in 1903, he continued as attorney and also was given charge of legal work for the Tacoma smelter. In 1912 he became western counsel of Asarco and in 1916 came to New York as vice president and general counsel. He was chairman of the board from 1930 to 1947 when he retired. Mr. Brownell was an advocate of international bimetallism and during World War II urged the adoption of such bimetallism by agreement of the leading commercial nations of the world. He said the plan would retain every advantage of the international gold standard and yet assure an adequate supply of monetary metals for the post-war period.

Mr. Brownell served as president and chairman of the board of Federal Mining & Smelting Co., chairman of the board of General Cable Corp., and chairman of the executive committee, Revere Copper & Brass Inc. He was a former president of the Copper Institute and in 1932 presided over a world copper conference held in New York.

Oliver Hall (Member 1915) died Feb. 15, 1954. A consulting engineer and director of Noranda Mines Ltd., Toronto, Ont., he was one of Canada's most distinguished engineers. His obituary in *The Canadian Mining and Metallurgical Bulletin* read: "Acclaimed by all as the greatest 'mine finder' and 'mine maker' of his time, his remarkable success in developing mines was little short of uncanny." Mr. Hall was born in Washington, Ont., in 1879. He received his B.S. degree from McGill University in 1903 and his M.S in 1904. He joined Mond Nickel Co. as exploration engineer in 1905. He recommended the purchase of Mond Frood and Levack mines and was made superintendent of mines in 1910 and mines manager in 1918. When Mond and International Nickel Co. of Canada merged in 1929, Mr. Hall was placed in charge of all Inco mines with the title of general superintendent of mines. He joined Noranda Mines Ltd. in 1931 as assistant general manager. Mr. Hall was also a consulting engineer for Quemont Mining Corp., vice president of Hallnor Mines, and a director of Kerr-Addison Gold Mines, Waite-Amulet Mines, and many other companies. He was a Life Member of the Canadian Institute of Mining & Metallurgy and served as a Member of the Council from 1937 to 1939 and vice president from 1939 to 1940. Mr. Hall was a past president of the Ontario Mining Assn.

Ames B. Hettrick (Member 1936) died Dec. 27, 1953. Mr. Hettrick, manager of engineering and development, Calco Chemical Div., American Cyanamid Co., Bound Brook, N. J., was closely associated with the development of titanium dioxide pigments. He was born in Clinton, Iowa, in 1904. He worked as a construction engineer for Stone & Webster Engineering Corp. from 1922 to 1924, then studied at Massachusetts Institute of Technology from 1924 to 1928. Returning to Stone & Webster, he supervised the installation of equipment for the electrification and mechanization program of the Philadelphia & Reading Coal & Iron Co. From 1930 to 1931 he installed the equipment in the concentrating mill and chemical plant for Southern Mineral Product Corp., and then joined this company as chief engineer, later becoming plant superintendent. When Southern Mineral was purchased by Virginia Chemical Corp. in 1936, Mr. Hettrick was made vice president and general manager of the new organization. When Cyanamid's Calco Chemical Div. acquired these interests in 1944, he became works manager of the Piney River, Va., plant operation. Mr. Hettrick was made assistant manager of manufacturing for Calco Chemical in 1947.

Philip M. LeBaron (Member 1952) died Feb. 7, 1954. He was a mining geologist and field engineer. Mr. LeBaron was born in Oxford, Ohio, in 1911 and received his B.S. in chemistry from Alabama Polytechnic Institute in 1934 and his M.A. in geology from the University of North Carolina in 1937. He gained his early experience in gold mines in North Carolina and spent a year as junior geologist with the U. S. Geological Survey. He worked later for the American Zinc Co. of Tennessee, Mascot, Tenn., the Solvay Process Co., Syracuse, N. Y., General Chemical Co., New York, and more recently for the Dicalite Div., Great Lakes Carbon Corp., Los Angeles.

Necrology

Date Elected	Name	Date of Death
1904	John J. Blow	Unknown
1948	C. O. Denning	Feb. 12, 1954
1948	Wendell F. Hess	Apr. 21, 1954
1904	H. Hunter	Sept. 24, 1947
1903	Howard W. Throckmorton	Feb. 22, 1954
1928	William H. Whittekin	Apr. 10, 1954
1900	George J. Young	Apr. 8, 1954

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Orville R. Lyons (Member 1940) died Feb. 2, 1954. He was preparation manager, Republic Steel Corp., Cleveland, Ohio. Mr. Lyons was born in Staples, Minn., in 1912, and received his B.S. in mining in 1934 and his B.S. in geology in 1935 from the University of North Dakota. After working with Philadelphia & Reading Coal & Iron Co. and Gill Rock Drill Co. in Pennsylvania, he studied at the the University of Alabama on a U. S. Bureau of Mines Fellowship, receiving an M.S. in mining in 1940. He was later a research engineer for Battelle Memorial Institute and a coal preparation engineer for Heyl & Patterson. Mr. Lyons wrote and published several technical articles and was the author of the chapter on dewatering and thermal drying in the second edition of *Coal Preparation*. He was Program Chairman of the AIME Coal Div. from 1950 to 1952, Chairman of the Subcommittee on Coarse Coal Cleaning from 1953 to 1954, and on the Coal Div. Executive Committee from 1952 to 1956.

Paul R. Moyer (Member 1942) died Dec. 19, 1953. Mr. Moyer was chief, Rock Machinery Branch, Mining Machinery Div., NPA, Washington, D. C. He was born in 1904 and graduated from Pennsylvania State University in 1925 with a B.S. in mining engineering. He worked from 1925 to 1933 with Bethlehem Mines Corp., Cornwall, Pa., as mine and construction engineer and also as a mine foreman. Mr. Moyer was later explosives engineer for Philadelphia & Reading Coal & Iron Co., Pottsville, Pa., and then engineer and foreman for Thomas Iron Co., Wharton, N. J. In 1941 he joined the U. S. Bureau of Mines and was for many years in the Health & Safety Branch, Safety Div.

Edgar F. Schaefer, 58, president of the Gardner-Denver Co. and widely known as an industrial leader, died suddenly at his home in Quincy, Ill., May 2, 1954.

Mr. Schaefer first joined the Gardner-Denver Co., manufacturers of air compressors, rock drills and air tools, in 1919, serving as cost clerk. Through rapid promotions, he became export manager and then assistant sales manager. In 1926 he was made vice president in charge of sales and was named as a member of the Gardner-Denver board of directors. He was elected executive vice president in 1942 and became president 5 years later.

Throughout his career, Mr. Schaefer was active in industrial and commercial organizations. He was past president of the Compressed Air Institute, a past member of the board of directors of the Hydraulic Institute, a past director of the Illinois State Chamber of Commerce and of the Quincy Chamber of Commerce, and a member of the board of directors of the Industrial Assn. of Quincy. At the time of his death, he was a director of the Executive Committee of the Machinery and Allied Products Institute.

Mr. Schaefer was also prominent in many civic, welfare, and educational organizations and enterprises. These included service as a director of the Illinois Heart Assn., member of the President's Council of Carthage College, and member of the board of trustees of a home for the aged and of a home for children.

A graduate of the University of Illinois, Mr. Schaefer was an army pilot in World War I, and saw action in France. He was also a member of the War Production Board.

Jacques van Tijn (Member 1943) died Mar. 13, 1954. He was a mining engineer, vice president of Mining Equipment Corp., New York, consulting engineer for Ore Trading Corp., New York, and director of Dominion Manganese Corp., of Richmond, Va., and New York. Mr. van Tijn was born in 1893 in Holland and graduated from Delft University in Holland in 1920. After that he was consulting geologist and later chief engineer for several Dutch concerns in South Africa and Holland. He came to the U. S. in 1940 and in 1941 joined the Mining Equipment Corp. (a subsidiary of the Billiton Co. of The Hague, Holland) of which company he was a vice president.

Arthur Waldman (Member 1952) died Mar. 10, 1954 in Florida of a heart attack. Mr. Waldman was general superintendent, U. S. Steel Corp., Coal Div., Uniontown, Pa. Born in Philadelphia in 1908, he received an E.M. from Lehigh University in 1929. Mr. Waldman was employed by the Philadelphia & Reading Coal & Iron Co., Pottsville, Pa., from 1929 to 1936, and during this period taught a night mining school under the supervision of Pennsylvania State University. He was at various times superintendent of Hamilton mine, Pratt City, Ala., chief engineer, coal mines, Tennessee Coal, Iron & R. R. Co., Birmingham, and general superintendent, Cia. Carbonifera de Sabinas S.A., Rosita, Coahuila, Mexico.

W. M. H. Woodward (Member 1933) died in Denver, Nov. 20, 1953. Mr. Woodward was a mining engineer retired from the U. S. Forest Service. He was born in Moniteau County, Mo., and graduated with an A.M. from Scarritt Collegiate Institute, Neosho, Mo., in 1895. He later worked at the Silver City Assay Office, Silver City, N. M. After working with various mining and milling companies in Arizona, he went to Mexico where he worked for several firms, among them Caborco Mines Co. and Tominil Mines Co. Before joining the U. S. Forest Service in 1914 as a mineral examiner, he was mill superintendent for United Mines Co., Tuolumne, Calif.

Appreciation of

George Joseph Young

by H. A. Geisendorfer

Mr. Young (Member 1900) was born in San Francisco, of pioneer parents, on Oct. 3, 1876, and died at his home in Oakland, Calif., Apr. 8, 1954 at the age of 77. He was graduated from the University of California with the class of 1899, as a Bachelor of Science, majoring in mining, and he then served as research assistant to Professor Christy. He became assistant professor of metallurgy at the University of Nevada, 1900 to 1903 and professor of mining and metallurgy from 1903 to 1913, and was in charge of the MacKay School of Mines from 1908 to 1913; professor of mining at the University of Minnesota, 1913 to 1916; and professor of metallurgy at the Colorado School of Mines, 1916 to 1917.

In 1918, he joined the staff of *Engineering & Mining Journal* as assistant editor, and later became managing editor, and in 1922 editor of the Western Div., with headquarters in San Francisco. He loved the West, and chose to stay in San Francisco rather than go East.

He was the author of many publications, but his best known book, *Elements of Mining*, used extensively by the mining fraternity, was first published in 1916 and revised through four editions. It is still a standard reference book on mining methods and practices.

Mr. Young was a 50-year member of the AIME, a member of the Engineers Club of San Francisco for 41 years; and a member of the Sierra Club.

Mr. Young was a man of sterling qualities, and exemplary habits and a true and loyal friend. He had a keen and penetrating mind with a vast store of information always ready, and he had foresight and a determination that enabled him to complete whatever he undertook.

He was also an artist, and his camera and pictures were his hobby. He produced many fine etchings, and his photographs of the High Sierras and their enlargements are things of great beauty. He loved the High Sierras and with his wife spent his summers in the Yosemite Valley, and on the pack trails and lakes of its hinterland. With his camera and fishrod, he was always on the lookout for a good "shot" or a good fish stream.

He is survived by his wife, Hulda H. Young, a daughter, Mrs. Marian Sadusk, four sisters, and four grandchildren.

Proposed for Membership

MINING BRANCH, AIME

Total AIME membership on Apr. 30, 1954 was 20,519; in addition 1401 Student Associates were enrolled.

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The Institute desires to extend its privileges to every person to whom it can be of service, but does not desire as members persons who are unqualified. Institute members are urged to review this list as soon as possible and immediately to inform the Secretary's office if names of people are found who are known to be unqualified for AIME membership.

In the following list C/S means change of status; R, reinstatement; M, Member; J, Junior Member; A, Associate Member; S, Student Associate.

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— Coming Events —

June 12, AIME Colorado Minerals Beneficiation Subsection, Annual Meeting, Climax, Colo.

June 14-18, American Society for Engineering Education Annual Meeting, University of Illinois, Urbana, Ill.

June 14-18, Second U. S. Congress of Theo. & Appld. Mech. Meeting, University of Michigan, Ann Arbor.

June 18, AIME, Spokane Subsection. Speaker, C. P. Love, plant manager, Kaiser Aluminum & Chemical Corp. Tacoma Works.

June 20-24, American Society of Mechanical Engineers, Wm. Penn Hotel, Pittsburgh.

June 20-25, American Institute of Chemical Engineers, nuclear energy meeting, University of Michigan, Ann Arbor, Mich.

June 21-25, AIEE, summer and Pacific general meeting, Biltmore Hotel, Los Angeles.

June 23-26, American Coal Sales Assn., Annual Convention, Colorado Springs, Colo.

June 25-26, 1954 Pacific Coast Regional Conference on Clays and Clay Technology, University of California, Berkeley, Calif.

July 5-9, American Assn. for Advancement of Science, Gordon research conference on flotation, Kimball Union Academy, Meriden, N. H.

July 25-Aug. 10, World Power Conference, Sectional Meeting, Rio de Janeiro, Brazil.

Aug. 2-12, Pan American Federation of Engineering Societies (UPADI), 3rd Convention, Sao Paulo, Brazil.

Sept. 8-10, American Society of Mech. Engrs., Fall Meeting, Schroeder Hotel, Milwaukee.

Sept. 10, AIME Lehigh Valley, Annual Inspection Trip, Ingersoll-Rand Co., Phillipsburg, N. J.

Sept. 20-24, American Mining Congress, Civic Auditorium, San Francisco.

Sept. 23-24, Central Pennsylvania Coal Producers Assn., Annual Meeting, Bedford Springs Hotel, Bedford, Pa.

Sept. 24, AIME, Minerals Beneficiation Div., Fall Meeting, Fairmont Hotel, San Francisco.

Sept. 30, AIME Utah Section, Stag: cocktails, dinner, smoker, 7:00 pm Newhouse Hotel.

Oct. 5-9, AIME Industrial Minerals Div., Fall Meeting, Whiteface Inn, Lake Placid, N. Y.

Oct. 26, Assn. of Consulting Chemists and Chemical Engineers Inc., annual symposium and banquet, Hotel Belmont Plaza, New York.

Oct. 27-29, Clay Mineral Technology, Third National Clay Minerals Conference, Rice Institute, Houston. Those interested in presenting papers should announce their intentions to A. F. Frederickson, Washington University, St. Louis, on or before July 15.

Oct. 28-29, AIME, ASME Fuels Conference, William Penn Hotel, Pittsburgh.

Oct. 29, AIME, NOHC and Pittsburgh Local Section, off-the-record meeting, William Penn Hotel, Pittsburgh.

Oct. 29-30, AIME, Industrial Minerals Div., Rocky Mountain Region Industrial Minerals Conference, Salt Lake City. Registration Oct. 28.

Nov. 1-3, AIME, Institute of Metals Div., fall meeting, Hotel Morrison, Chicago.

Nov. 1-3, Geological Society of America and Associated Societies, Statler and Biltmore hotels, Los Angeles.

Nov. 12, Illinois Mining Institute, Hotel Abraham Lincoln, Springfield, Ill.

Nov. 13-18, ASME, 75th Anniversary Meeting, Congress & Hilton, Chicago.

Nov. 18, AIME, Utah Local Section, joint meeting with Intermountain Assn. of Petroleum Geologists, 8:00 pm, Newhouse Hotel, Salt Lake City.

Nov. 18, American Mining Congress, Coal Div., Wm. Penn Hotel, Pittsburgh.

Dec. 1-3, AIME Electric Furnace Conference, William Penn Hotel, Pittsburgh.

Dec. 12-15, American Institute of Chemical Engineers, Annual Meeting, Statler Hotel, New York.

Feb. 14-17, 1955, AIME, Annual Meeting, Conrad Hilton Hotel, Chicago.

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